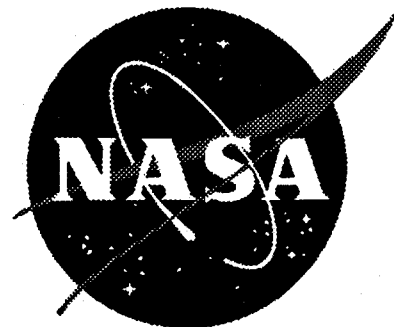


GUIDE FOR
SPECIFYING
EQUIPMENT NOISE
EMISSION LEVELS

By
Hoover & Keith Inc.

NASA Lewis Research Center

Guide for Specifying Equipment Noise Emission Levels



H&K Final Report No. 1240

H&K Job No. 2290

26 November, 1996

Prepared for:

The Bionetics Corporation
1100 Apollo Dr.
Brook Park OH 44142



Submitted By:

David A. Nelson
Hoover & Keith Inc.
11381 Meadowglen, Suite I
Houston, TX 77082
Phone: (713) 496-9876
Fax: (713) 496-0016



Acoustics
Noise Control
Vibration Control

Houston, TX, USA

Hoover & Keith Inc.

STANDARD GUIDE FOR SPECIFYING EQUIPMENT NOISE EMISSION LEVELS

NASA Lewis Research Center, Cleveland, Ohio

EXECUTIVE SUMMARY

This guide covers the development of criteria for noise emission from a broad variety of fixed and portable equipment purchased for use at NASA Lewis Research Center (LeRC), including equipment purchased by Contractors. It is intended specifically for equipment expected to produce noise approaching hearing conservation levels of 80 dBA and higher under a variety of siting and operational considerations.

Proper specification of low-noise equipment is an integral part of engineering noise controls required by the NASA Lewis Research Center (LeRC) and Occupational Safety and Health Administration (OSHA) regulations.

This guide is designed primarily to support hearing conservation goals, although community noise and speech communication in control rooms are also addressed.

Equipment is classified into five groups, each with a corresponding baseline noise emission criterion:

- Group 1: Heavy Machinery,
- Group 2: Vents to Atmosphere,
- Group 3: Piping and Ductwork,
- Group 4: Light Machinery, and
- Group 5: Electrical Transformers.

Adjustments are applied to the baseline noise emission criterion for various siting and operational considerations, yielding the maximum permissible sound level (MPSL). Additionally, maximum permissible octave band sound power levels (PWL) are specified for outdoor equipment, based on a limiting spectrum designed to avoid community noise problems. A "Noise Emission Worksheet for New Equipment" is provided which guides the user through these steps. Finally, recommended specification language is identified which may be incorporated into comprehensive equipment specifications. A computer diskette containing a Microsoft Excel-compatible computer spreadsheet version of the worksheet and an ASCII-text computer file containing the specification language is also furnished with the guide.

A method for optional post-installation verification is provided for use by the Purchaser.

STANDARD GUIDE FOR SPECIFYING EQUIPMENT NOISE EMISSION LEVELS

NASA Lewis Research Center, Cleveland, Ohio

TABLE OF CONTENTS

	Page
1.0 INTRODUCTION	1
1.1 Policy	1
1.2 Scope	1
1.3 Significance and Use	2
1.4 Technical Feasibility	3
2.0 EQUIPMENT GROUPS	4
2.1 Application Notes for Cooling Towers	6
2.2 Application Notes for Reciprocating Engines	6
2.3 Gas Turbine Equipment	6
2.4 Noise Radiated from Connected Piping, Ductwork and Extended Surfaces	6
3.0 NOISE EMISSION LIMITS	7
3.1 General Comments	7
3.2 Maximum Permissible Sound Level (MPSL)	7
3.3 Maximum Permissible Octave-Band Sound Power Level	12
4.0 NOISE EMISSION WORKSHEET FOR NEW EQUIPMENT	13
5.0 SPECIFICATION LANGUAGE	16
5.1 Information Required with Submittal	16
5.2 Equipment Loading and Conditions	17
5.3 Maximum Permissible Sound Level (MPSL)	17
5.4 Maximum Permissible Octave Band Sound Power Levels (PWL)	17
5.5 Warranty of Equipment Noise Emission	18
5.6 Vibration Isolation	19
5.7 Contractor Submittal Form	19

TABLE OF CONTENTS (cont'd)	Page
Appendix A DEFINITION OF TERMS	21
Appendix B SOUND LEVELS FROM TRANSFORMERS	24
Appendix C EXAMPLES OF COMPLETED WORKSHEETS	27
C.1 Steam Vent to Atmosphere, Outdoors in Reverberant Courtyard	27
C.2 Centrifugal Chiller in Unattended Acoustical Enclosure, Infrequent Operation	30
C.3 Air Compressor in Building 64, Intermittent Operation	33
C.4 Large Exhauster in Dedicated Sound-Isolating Building	36
C.5 Outdoor Ductwork Associated with Large Exhauster	39
C.6 Diesel-Powered Generator Set with On-Skid Enclosure	42
Appendix D EQUIPMENT SOUND-LEVEL VERIFICATION TEST FOR USE BY THE PURCHASER	45
D.1 Instrumentation	45
D.2 Loading	45
D.3 Measurement Locations	45
D.4 Microphone	48
D.5 Duration	49
D.6 Data to be Recorded	49
D.7 Correction for Background Noise	49
D.8 Averaging over Measurement Locations	49
D.9 Adjustment to Free-Field Conditions	50
Appendix E REFERENCES	51
E.1 Addresses of Standards and Test Code Organizations	51
E.2 Titles of Test Codes	52

TABLE OF CONTENTS (cont'd)**Page****Tables**

Table 1	Equipment Groups and Test Code Citations	5
Table 2	Baseline Noise Emission Criteria	7
Table 3	Adjustments for Maximum Permissible Sound Level	8
Table 4	Maximum Permissible Octave Band Sound Power Level, Outdoor Equipment	12
Table O-2	Audible Sound Levels for Oil-Immersed Power Transformers	25
Table O-3	Audible Sound Levels for Liquid-Immersed Distribution Transformers and Network Transformers	26
Table O-4	Audible Sound Levels for Dry-Type Transformers 15000-Volt Nominal System Voltage and Below	26
Table D.1	Field Verification Test Measurement Configurations	46
Table D.2	Background Noise Corrections	49
Table D.3	Adjustment to Free-Field Conditions	50

Figures

Figure 1	Determining the Existence of a Reverberant Condition	11
Figure 2	Description of Measurement Locations by Configuration	47-48

1.0 INTRODUCTION

1.1 Policy

Occupational Safety and Health Administration (OSHA) regulations¹ require administrative or engineering noise control for areas where personnel receive time-weighted average noise exposures in excess of 90 dBA. The NASA Health Standard on Hearing Conservation² requires similar controls for areas where noise exposure is in excess of 85 dBA. Many areas of NASA LeRC approach or exceed these noise exposure levels; action must be taken to bring existing areas into regulatory compliance, and to ensure compliance for new installations. Proper specification of low-noise equipment is an integral part of engineering noise controls required by these regulations. In addition, consistent use of this guide is an important component of bringing about reductions in noise levels, reduction of administrative and operational noise controls, and improvement in the safety, comfort and regulatory compliance of the work environment.

1.2 Scope

This guide covers the development of criteria for noise emission from a broad variety of fixed and portable equipment purchased for use at NASA Lewis Research Center (LeRC), including equipment purchased by Contractors. It is intended specifically for equipment expected to produce noise approaching hearing conservation levels of 80 dBA and higher under a variety of siting and operational considerations.

This guide is not a standard NASA LeRC specification for any particular piece of equipment, but rather is intended to permit designers and engineers to identify appropriate noise emission requirements and incorporate them into comprehensive equipment specifications.

Equipment with mechanical power less than 2 HP (1.49 kW) may not need to be specified according to this Guide. For new equipment with mechanical power greater than 3,000 HP (2,200 kW) or for refrigeration equipment with capacity in excess of 500 tons (60,000 BTU/hr, or 60 MJ/hr), this Guide may provide insufficient direction for effective noise control. In addition, installations on floors above occupied spaces have special noise control challenges which are outside the scope of this guide. For installations outside the scope of this guide, it is recommended that assistance be requested from the NASA LeRC Noise Exposure Management Program (NEMP, x3-3950).

¹ General Industry Occupational Noise Standard, 29 CFR 1910.95, Occupational Safety and Health Administration

² NASA Health Standard on Hearing Conservation, NHS/IH 1845.4, June 1991

This guide is designed primarily to support hearing conservation goals. Separate and potentially more stringent noise emission requirements may apply where other goals, such as speech communication, are prominent. Note that levels that meet hearing conservation requirements are not necessarily "quiet", e.g., they do not guarantee an office environment in the immediate vicinity.

Noise emission criteria are expressed in terms of maximum permissible A-weighted sound pressure level (sound level) and octave-band sound power levels (PWL) generated by a single piece of equipment under a specified load. The criterion levels are selected to support NASA LeRC hearing conservation goals and to take advantage of the most current advances in noise control technology.

Excluded from the scope of this guide are technical and other considerations that do not pertain to noise emission. This guide is not intended to apply to specialized research items, such as jet engines and rocket nozzles, which might be expected to create large amounts of noise. Noise generated by research operations is covered by the NASA LeRC Safety Permit Process.

1.3 Significance and Use

Selection of low-noise equipment is generally the most effective method of reducing noise exposure. Equipment designed for reduced noise emission can be sited more flexibly and reduces reliance on personal hearing protection. In addition, noise control treatments designed and installed by the equipment manufacturer typically provide better equipment accessibility than aftermarket treatments, improving convenience of operation, observation and maintenance. Finally, single-point responsibility for noise emissions is maintained.

Past experience in industry indicates that the added cost for low noise equipment is approximately 0.4% to 2.0% of the total project cost. If low-noise equipment is not specified and noise controls are required at a later date, costs can exceed 5% of the total project cost.

It is understood that newer, quieter equipment specified according to this guide will occasionally be sited alongside older, noisier equipment. In such cases, the impact of specifying reduced noise emission may not be immediately apparent. However, with time and consistent specification of equipment in accordance with this guide, significant long-term improvement in the noise environment is expected.

General guidance on the benefit of pre- and post-installation testing are provided in Appendix D (Page 45), including an optional procedure for post-installation noise emission verification for use by the Purchaser.

1.4 Technical Feasibility

The specified noise emission levels in this Guide have been compared with actual acoustical data for many types of available equipment and are believed to be achievable in most cases. Following a worldwide trend toward design of quieter machinery, many manufacturers have already incorporated adequate noise controls into their standard designs or provide low-noise versions of popular equipment. If, after consultation with several manufacturers, it appears that the desired noise emission levels cannot be achieved without significant penalties in cost, performance, or access to equipment, assistance should be requested from NEMP.

2.0 EQUIPMENT GROUPS

Equipment Group designations, and test code citations corresponding to particular types of equipment are presented in Table 1 (Page 5). Equipment is classified into five groups:

- Group 1: Heavy Machinery,
- Group 2: Vents to Atmosphere,
- Group 3: Piping and Ductwork
- Group 4: Light Machinery, and
- Group 5: Electrical Transformers.

Group 3 applies to sound radiated from piping, ductwork, and other extended surfaces that originates from equipment noise or vibration (e.g., blowers, control valves) or as flow-generated noise, more than 3 meters distant from equipment items classified in other Groups.

The test codes cited are typical for measurements made by the Manufacturer in prototype or production testing. Titles of Test Codes and addresses of the sponsoring organizations are listed in Appendix E (Page 50).

If the equipment under consideration is not listed in Table 1, the user has three options:

1. consult with equipment manufacturers to determine standard industry practice,
2. consult NEMP, or
3. make reference to a general purpose industrial noise measurement standard such as ANSI-ASME PTC-36, "Measurement of Industrial Sound".

Section 2.1 through 2.4 (Page 6) furnish notes on use of this guide for cooling towers, gas turbines, reciprocating engines, and machinery noise radiating from attached structures such as piping and ductwork.

Table 1: Equipment Groups and Test Code Citations

Equipment Group		Typical Test Code used by Manufacturer in Pre-Installation Testing
Group 1	<u>Heavy Machinery</u> <ul style="list-style-type: none"> Reciprocating Engines Gas and Steam Turbines Rotating Electric Machinery Hydraulic Motors Hydraulic Pumps <ul style="list-style-type: none"> Valves, Throttles and Orifices Gears Compressors, Exhausters Blowers and Fans Chillers Boilers Heaters Dryers, Coolers Cooling Towers Machine Tools Electric Power Tools Pneumatic and Air-Powered Equipment Industrial Trucks Fabrication Equip. greater than 10 HP 	ANSI/ASME PTC-36 ANSI B133.8 IEEE-85 ANSI B93.72M ANSI B93.71M ANSI/ISA S75.07 ANSI/AGMA 6025-C90 ANSI/ASME PTC-36 ANSI/ASME PTC-36 ARI 575 ANSI/ASME PTC-36 API RP 531M API RP 631M CTI NMTBA ANSI S12.15 ANSI/CAGI S5.1 ANSI/ASME B56.11.5 ANSI/ASME PTC-36
Group 2:	<u>Vents to Atmosphere</u> Blowdowns, Relief Vents for Air, Steam, Nitrogen	ANSI/ASME PTC-36
Group 3:	<u>Piping and Ductwork</u> <ul style="list-style-type: none"> Piping Ductwork 	ANSI/ASME PTC-36 ANSI/ASME PTC-36
Group 4:	<u>Light Machinery</u> Building Ventilation Fans or Blowers Fabrication Equip. less than 10 HP Pedestal and Shop Fans	ANSI/ASME PTC-36 ANSI/ASME PTC-36 ANSI/ASME PTC-36
Group 5:	<u>Transformers</u> Oil-filled Dry-Type below 15 kV Liquid-Immersed	ANSI/IEEE C57.90 ANSI/IEEE C57.94 ANSI/IEEE C57.90

• denotes that special application notes for this type of equipment follow.

2.1 Cooling Towers

For the purposes of this guide, each cell of the cooling tower is treated as a separate piece of equipment: MPSL and PWL specifications apply to fan and water noise generated by each individual cell.

A maximum fan tip speed of 50 meters per second shall be observed for propeller bladed equipment.

2.2 Reciprocating Engines

Where reciprocating engines are sited indoors, the cooling fan and/or exhaust are sometimes located outdoors. In this event, separate MPSL requirements apply for the indoor and outdoor equipment components.

2.3 Gas Turbine Equipment

Gas turbine equipment is usually located within a host building, with inlet and exhaust ducted to outdoors. In this event, separate MPSL requirements apply for the indoor and outdoor equipment components.

2.4 Heavy Machinery Noise Radiated from Connected Piping, Ductwork and Structures

Vibrational energy created by Group 1 machinery can be radiated from connected piping, ductwork, or lightweight structures. At distances greater than 3 meters from the machinery, the Group 3 noise criterion applies. Specification of piping or ductwork noise emissions in this case should be addressed to the Contractor providing the equipment under consideration.

NOTE - This may require separate MPSL requirements for one piece of machinery: one for noise emitted directly by the machinery, and the other for noise originating at that machine, but emitted from attached structures.

3.0 NOISE EMISSION LIMITS

3.1 General Comments

Equipment noise levels shall not exceed the maximum permissible sound level (MPSL) determined in accordance with this guide. Octave band sound power levels shall not exceed the maximum permissible levels indicated in Section 3.3 (Page 12).

Noise emission limits apply to individual equipment pieces or packages. For the purposes of this guide, a package of equipment is defined as components connected by a shaft (such as a diesel-powered electric generator) which are obtained from one supplier, or for which noise emission figures are specified as an integrated unit. For example, a single electric motor or a motor/pump combination can be specified as a unit according to this guide, but a group of mechanically independent electric motors must be treated as separate items.

Equipment loading may have a strong influence on equipment noise emission. Although maximum equipment loading usually results in highest noise emission, in some cases the highest sound levels may be observed at reduced equipment loads. For this reason, it is important to specify the expected range of operating conditions over which the specified noise emission levels apply.

3.2 Maximum Permissible Sound Level (MPSL)

A baseline noise emission criterion (in dB re 20 μ Pa) for each Equipment Group is presented in Table 2 below (Page 7). This criterion applies to average sound levels at a distance of 1 meter from the specified equipment, as determined under the specified loads using the Test Procedure for Post-Installation Verification (Appendix D, page 45). The geometry of measurement locations used in pre- and post-installation tests varies by application.

Table 2: Baseline Noise Emission Criteria	
Equipment Group	Baseline Noise Emission Criterion, dBA
Group 1: Heavy Machinery	85 dBA
Group 2: Vents to Atmosphere	85 dBA
Group 3: Piping and Ductwork	80 dBA
Group 4: Light Machinery	80 dBA
Group 5: Transformers	NEMA TR-1 (as tabulated in Appendix B, Pages 25 and 26)

The MPSL for transformers may be obtained from Tables O-2, O-3 and O-4 of NEMA TR-1³, which are reprinted in Appendix B (Pages 25 and 26), from NEMA TR-1 by permission of The National Electrical Manufacturers Association.

The MPSL may differ from the baseline noise emission criterion, depending on seven adjustments which take into account various siting and operational characteristics. The adjustments (see Table 3 below, Page 8) apply to equipment in Groups 1 through 4 only: no adjustments are applied to Group 5 equipment. The adjustments are additive and, with one exception, are independent of one another. The exception is the adjustment for an adjacent test cell control room, which presupposes the existence of a sound-isolating enclosure around the equipment. The maximum total adjustment permitted is +25 dBA. Negative adjustments, where applicable, are mandatory.

Table 3: Adjustments for MPSL	
Condition	Adjustment (dBA)
a. Unattended Sound-Isolating Enclosure	+20
b. Control Room and Sound-Isolating Enclosure	- 10
c. Remote Outdoor Site: no personnel within 3 meters	+ 5
d. Infrequent Operation: < 15 shifts per year	+ 5
e. Intermittent Operation: < 30 min./shift, < 6 times/hour (not for use with Group 2)	+ 5
f. Reverberant Environment	- 5
g. High Equipment Density: >5 noise-producing items within a 3-meter radius	- 5

a): Unattended Sound-Isolating Enclosure

An unattended sound-isolating enclosure is defined as any structure that houses the equipment under consideration, provides significant acoustical isolation, and is not occupied by personnel. A prefabricated industrial noise enclosure, a dedicated mechanical room, or a test cell can serve this purpose if properly designed. In order to qualify for this adjustment, the following conditions must be met:

- » personnel are present inside the enclosure and exposed to noise exceeding an 80 dBA threshold fewer than 30 minutes per shift,
- » the enclosure is not provided by the manufacturer as a noise control element, (e.g., an on-skid enclosure supplied with a diesel generator set),
- » the enclosure walls and ceiling weigh at least 25 kilograms per square meter, and possess a Sound Transmission Class (STC) rating of 45 or greater,
- » doors and windows possess a rating of STC 42 or greater,

³ NEMA Standards Publication No. TR 1-1993, "Transformers, Regulators and Reactors", 1994, National Electrical Manufacturers Association

- » all ventilation, cable and other penetrations through the enclosure shell are acoustically treated to be compatible with STC 45 walls,
- » all gaps in exterior surfaces are sealed with grout or non-hardening acoustical caulk, and
- » untreated cracks and gaps constitute an area less than 0.1% of the total.

With this adjustment in place, the MPSL applies to noise as measured *inside* the sound-isolating enclosure. Thus, a unit that would otherwise be specified at 85 dBA could be specified for 105 dBA noise emission if so enclosed, while maintaining sound levels of 85 dBA or less outside the sound-isolating enclosure. For on-skid enclosures supplied with equipment, the adjustment does not apply and sound levels 1 meter from the exterior of the on-skid enclosure are relevant.

b): Control Room Adjacent to Equipment

This adjustment reduces permissible noise emissions in order to promote acceptable speech communication in control rooms. The adjustment is relevant under the following conditions:

- » the equipment is enclosed in a sound-isolating enclosure (as described in 3.2a above),
- » the control room is a sound-isolating enclosure (as described in 3.2a above),
- » one or more surfaces of the control room are exposed to the sound field inside the sound-isolating enclosure (e.g., the enclosure and control room share a common wall),
- » two or more persons simultaneously occupy the control room,
- » speech communication is important to the safe operation of the equipment, and
- » no personal hearing protection devices are worn inside the control room.

If the test cell is physically remote from the sound field inside the enclosure (e.g., a free-standing control room located next to, but not attached to, an equipment enclosure), this adjustment does not apply.

The control room adjustment does not apply when equipment is unenclosed. In this case, hearing conservation requirements for personnel outside the control room take precedence.

c): Remote Outdoor Site

This adjustment applies if the equipment is located at an outdoor site more than 3 meters away from areas frequented by personnel or passersby.

d): Infrequent Operation

This adjustment applies to equipment which is operated for any length of time during fewer than 15 eight-hour shifts per year.

e): Intermittent Operation

This adjustment applies to equipment which produces noise for less than 30 minutes per shift and fewer than six times per hour. No such allowance shall be made for noise of a periodic or hammering character. This credit may not be applied to Group II equipment (Vents to Atmosphere), the intermittent character of which has already been taken into account.

f): Reverberant Environment

This adjustment shall be used for equipment placed in host spaces or sound-isolating enclosures that are deemed to be reverberant for the purposes of this standard.

NOTE - Outdoor spaces which have at least two man-made surfaces, such as equipment courtyards, can also be reverberant.

A simple method is provided for allowing the user to determine if the environment is reverberant. This determination is made by separately totaling the acoustically absorptive and reflective surface areas of the host space or enclosure, and then locating the corresponding point on Figure 1 (Page 11). Points falling below the line indicate a reverberant condition (for which the -5 dBA adjustment applies); points falling above the line indicate a non-reverberant condition.

Sound absorbing surfaces include:

- » glass fiber, mineral fiber, or basalt wool with thickness of 50 mm or greater applied to room surfaces,
- » open-cell foam with thickness of 75 mm or greater applied to room surfaces,
- » Tectum® with thickness of 50 mm or greater when mounted on furring strips 40 mm or more away from room surfaces,
- » acoustical ceiling tiles in a grid ceiling with a 400 mm deep plenum,
- » hanging acoustical baffles with thickness of 50 mm or greater (for which the area of one face is to be used in calculations), and
- » openings such as open windows, doors, or "missing" walls.

Sound reflecting surfaces include:

- » brick, stone, concrete, cinder blocks,
- » wood, glass, metal, gypsum board,
- » tile, plaster, ground, and

» closed cell foams.

For environments having sound-reflective surface area greater than 2000 square meters, no further acoustical treatment is required to achieve the non-reverberant condition.

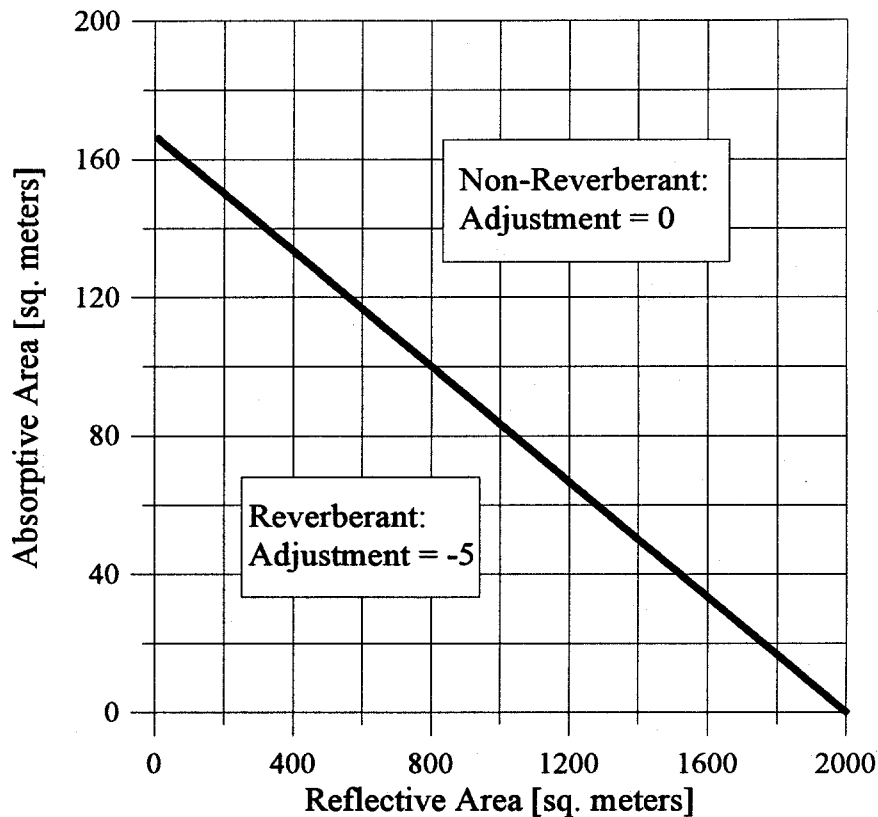


Figure 1: Determining the Existence of a Reverberant Condition

g): High Equipment Density

Noise levels from equipment are additive. When several equipment items are located within a small area, the local sound level can be significantly elevated relative to a single equipment item.

This adjustment shall be used if more than 5 pieces or packages of noise-emitting equipment covered by this guide, whether new or pre-existing, are located within a 3 meter radius of the piece of equipment being specified.

With regard to piping and ductwork, a high equipment density shall be deemed to exist if more than five pipes or ducts covered by this guide are located within a 3-meter radius of the pipe or duct being specified.

3.3 Octave Band Sound Power Level

Maximum octave band sound power level (PWL) are specified for unenclosed equipment sited outdoors, and for equipment with a contractor-supplied enclosure that is sited outdoors. The PWL (in dB re 10^{-12} watt) shall not exceed a limiting spectrum, presented in Table 4 (Page 12), for which the possibility exists of sporadic, nighttime complaints from residents in the nearby community.

Table 4: Maximum Octave Band Sound Power Levels (dB re 1 pW)								
Octave Band Center Frequency (Hz)	63	125	250	500	1000	2000	4000	8000
All Groups	127	120	113	110	108	107	107	106

NOTE - The PWL specification may be more restrictive than the MPSL specification for outdoor sources.

4.0 WORKSHEET

A "Noise Emission Worksheet for New Equipment" (Worksheet) has been developed to assist with calculations made according to this guide. A blank copy of the Worksheet and the associated Schedule A is provided on Pages 14 and 15. Gray boxes provide information used in calculations.

Information required in order to complete the worksheet and Schedule A is as follows:

- » The mechanical power or capacity of the equipment being specified,
- » The applicable Equipment Group number,
- » Construction of sound-isolating enclosures and test cells, if any,
- » Proximity to personnel, passersby, and nearby noise-producing equipment,
- » Timing of operations,
- » The volume (cubic meters), and sound-absorbing and sound-reflecting surface areas (square meters) of the host space or sound-isolating enclosure,

The Worksheet guides the user through the following steps:

- » record relevant information on the equipment,
- » determine if the equipment falls within the general scope of the guide,
- » identify the corresponding baseline noise emission criterion,
- » total the adjustments and calculate the adjusted MPSL, and
- » display, if applicable, the maximum permissible PWL spectrum.

Schedule A guides the user through a comparison of the total sound-absorptive and sound-reflective areas, from which the determination of the reverberant condition is made.

A Microsoft Excel-compatible computer spreadsheet version of the worksheet (MNEW-1.XLS) is provided with this guide. Cells requiring user input have text highlighted in red. Other cells are automated to perform the necessary calculations and are "locked" to prevent accidental modifications. The spreadsheet is stored as a read-only file for a typical case; worked versions of the spreadsheet may be saved under a different file name.

Examples of completed worksheets for a number of common installations are presented in Appendix C (Page 27).



NOISE EMISSION WORKSHEET FOR NEW EQUIPMENT

Rev. 1, November, 1996

Date	
Project	
By	
Sheet	of

to be used in conjunction with NASA LeRC "Guide for Specifying Equipment Noise Emission Levels"

1: ITEM DESIGNATION**BUILDING & AREA****2: RATED POWER OR CAPACITY OF EQUIPMENT (with units)****3: IS THE ITEM WITHIN THE SCOPE OF THE DOCUMENT? (Enter "Yes" or "No" as appropriate)**

3a: Is the mechanical power of this item less than 3000 HP (2,238 kW)?

OR

Is the cooling capacity of this item less than 500 Tons (60 MJ/hr)?

3b: Is the equipment to be installed on ground floor or with no occupants below?

If you answered "No" for either Line 3a or Line 3b, Complete this form and contact NEMP. Otherwise, Continue.

4: EQUIPMENT GROUP (See Section 2, Table 1)

4a: Enter number of Equipment Group

Group 1: Heavy Machinery

Group 2: Vents to Atmosphere

Group 3: Piping and Ductwork

Group 4: Light Machinery

Group 5: Transformers

5: BASELINE MAXIMUM PERMISSIBLE SOUND LEVELS (See Section 3.2, Table 2)

5a: Baseline Maximum Permissible Sound Level (dBA)

For Equipment Group Number 1 or 2, enter 85

For Equipment Group 3 or 4, enter 80

For Equipment Group 5, refer to NEMA TR-1 (Values Tabulated in Appendix B)

and Stop here.

6: ADJUSTMENTS FOR GROUPS 1, 2, 3 and 4 (See Section 3.2, Table 3)

For each case that applies, Copy the corresponding Adjustment into Column 1

	Adjust't	Column 1
6a. Unattended Sound-Isolating Equipment Enclosure: if "No", Skip to 6c	20	
6b. Control Room and Sound-Isolating Enclosure	-10	
6c. Remote Outdoor Site: no personnel within 3 meters	5	
6d. Infrequent Operation: operates during fewer than 15 8-hr. shifts per year	5	
6e. Intermittent Operation: < 30 min./shift, < 6 times/hr. Not for use with Group 2	5*	
6f. Reverberant Environment: Copy from Line A4 of Schedule A	-5	
6g. High Equipment Density: more than 5 pieces of equipment within a 3-meter radius	-5	

7: MAXIMUM PERMISSIBLE SOUND LEVEL AT 1 METER

7a: Sum applicable adjustments in Column 1

7b: Limit Credit to 25 dB: Enter the lesser of 25 and Line 7a

7c: Maximum Permissible Sound Level (MPSL): Add Line 5a and Line 7b >>>>>

8: MAXIMUM PERMISSIBLE OCTAVE BAND SOUND POWER LEVELS FOR OUTDOOR EQUIPMENT

8a: Is the Equipment Sited Outdoors? ("Yes" or "No")

(Note - This section applies to unenclosed outdoor equipment and to equipment with contractor-supplied enclosures)

8b: Max. Permissible PWL if Outdoors

8c: For Outdoor Equipment, Copy Line 8b

63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
127	120	113	110	108	107	107	106

Rev. 1. November. 1996

to be used in conjunction with NASA LeRC "Guide for Specifying Equipment Noise Emission Levels"

Date	
Project	
By	
Sheet	of

A1: Tabulate Sound-Absorptive and Sound-Reflective Areas in Square Meters

(Note - If Outdoors with no reflecting surfaces, use Absorbing Area = 200 sq. m.)

[illegible]

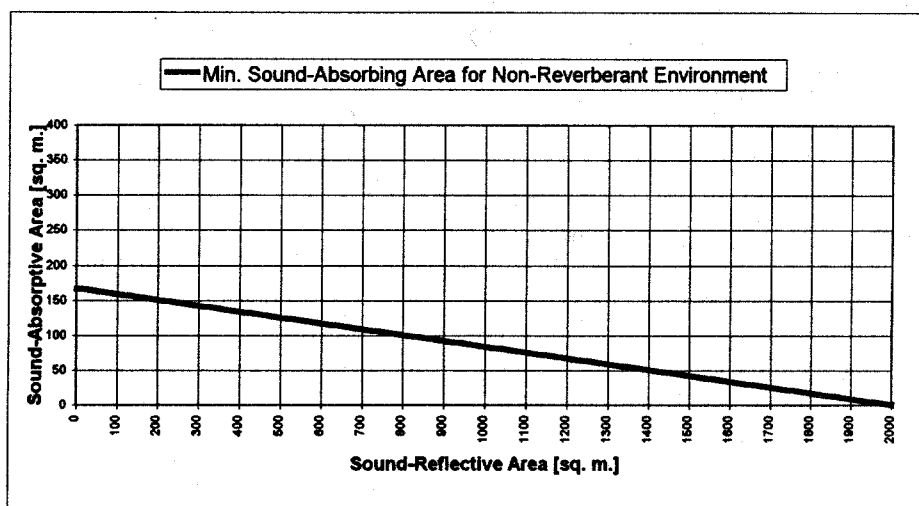
Glass Fiber	50 mm or thicker
Mineral Fiber	50 mm or thicker
Basalt Wool	50 mm or thicker
Open-Cell Foams	75 mm or thicker
Tectum on 40 mm airspace	50 mm or thicker
Acoustical Ceiling Tile	on 400 mm airspace
Hanging Acoustical Baffles	50 mm or thicker
Sky, Open Doors & Windows	

Brick, Stone, Concrete
Wood, Glass, Metal
Tile, Plaster
Gypsum Board
Closed-Cell Foams
Ground

A3: Total Reflective Area (Col. 2)

LOCATE THE POINT ON THE GRAPH CORRESPONDING TO THIS COMBINATION.
IF THE POINT IS BELOW THE LINE, THE ENVIRONMENT IS REVERBERANT.
IF THE POINT IS ABOVE THE LINE, THE ENVIRONMENT IS NON-REVERBERANT.

A4: If Reverberant, Enter "Yes" here and -5 in Col. 1 of Worksht. Line 6f



5.0 SPECIFICATION LANGUAGE

Specification language related to noise emission is provided below. The intent is that the user identify appropriate paragraphs for inclusion, fill in requested information, and incorporate the resulting noise emission specification language into the overall equipment specification.

Specification language is indented and italicized to differentiate it from the text of the guide, and appears in order as it would in a typical specification. Paragraphs marked "OPT." are optional and may be omitted as appropriate.

A Microsoft Word-compatible computer file (SPECLANG.DOC) containing the specification language is also provided with the guide. Placeholders for information required from the user are highlighted in red.

5.1 Information Required with Submittal

The following paragraphs describe the Contractor's responsibility for providing information related to equipment noise emission with project submittals.

The Contractor shall complete the attached submittal form and submit one for each specified loading condition with the quotation. When sound level data is requested and sound power level data is also available, this information shall be included.

OPT. NASA LeRC may permit alternate vendor submittal forms to be used by Contractors, provided that the information requested on the attached submittal form is furnished by the Contractor.

When noise emission requirements cannot be satisfied by the Contractor's standard design, alternatives for special design or for acoustical treatment of the standard design shall be quoted as a separate line item.

When an alternative or third-party acoustical treatment is quoted by the Contractor, the proposal shall contain all pertinent design details, cost, and effect on performance, if any.

Charges for testing and any increase in the quoted price, because of noise specifications, shall be noted in the overall equipment cost and shown as separate items in the Contractor's quotation.

NASA LeRC Guide for Specifying Equipment Noise Emission Levels

Abatement designs shall not limit equipment operations or accessibility, nor shall they conflict in any way with NASA LeRC safety and engineering standards.

5.2 Equipment Loading and Operating Conditions

The range of operating conditions expected for the specified equipment is (insert expected range of loading and operating conditions). Specified noise emission limits shall not be exceeded for operation at any point within this range.

The next two optional paragraphs apply to fabrication equipment or machine tools:

OPT. Equipment shall be operated at the required production rate and performing specified operations. (for use when the machine is specified for a specific purpose)

OPT. Equipment shall be operated in the unloaded mode of operation that generates maximum noise levels. (for use when the machine is purchased without specified tooling)

5.3 Maximum Permissible Sound Level (MPSL)

Equipment sound levels in decibels (re 20 μ Pa) at a distance of 1 meter from the equipment, shall not exceed (insert MPSL) dBA as measured in post-installation testing when operated under the loading conditions specified above. Post-installation sound testing will be conducted according to NASA LeRC "Equipment Sound-Level Verification Test For Use By The Purchaser".

5.4 Maximum Permissible Octave Band Sound Power Levels (PWL)

NOTE - This section applies only to equipment sited outdoors.

Equipment sound power levels, in decibels (re 1 picowatt), shall not exceed the values tabulated below in any octave band when operated under the loading conditions specified above.

	63	125	250	500	1000	2000	4000	8000
Sound Pressure Level	127	120	113	110	108	107	107	106

5.5 Warranty of Equipment Noise Emission

Verification of conformance to the specification is based on post-installation testing. Post-installation verification tests are recommended in all cases where the background noise levels can be made sufficiently low (e.g., by shutting off other equipment in the area). Performance of post-installation tests should be waived only when acceptable certified equipment sound-level test data are furnished by the Contractor.

Where equipment is to be installed in an environment that does not conform to the background noise requirements of the post-installation verification test (see Appendix D.7, Page 49), consideration should be given to requiring a pre-installation acceptance test performed by the Contractor at an acoustical laboratory or at the Contractor's facilities.

Pre-installation tests are helpful for identifying responsive bidders, and are occasionally necessary for verifying conformance to the specification where post-installation testing is not possible. Pre-installation tests consist of two types:

- a): tests on base models and prototypes, and
- b): tests performed on equipment with additional components, unique features, or special loading conditions specifically for the project under consideration.

Where the equipment to be purchased is fitted with standard components and is operated under typical load conditions, pre-installation test data obtained on base models is often sufficient to verify conformance. When additional components, unique features, or special loading conditions are expected, consideration should be given to requiring a pre-installation acceptance test performed by the Contractor at an acoustical laboratory or at the Contractor's facilities.

The Contractor's equipment shall not exceed the maximum permissible sound-level (MPSL) and, if applicable, the octave band sound power levels (PWL) stated in the specification. The Contractor shall be responsible for performing all remedial work necessary for compliance with these specifications at no additional cost to NASA LeRC.

OPT. A pre-installation acceptance test shall be performed by the Contractor. The test shall take place in the Contractor's facility, at a qualified laboratory, or at an installation in the field, according to (insert test code from Table 1, Page 5), on same or similar equipment operated under the load conditions specified above. The Contractor shall give notice three weeks prior to the date on which the laboratory, shop or field-witnessed test is to be made, so

that a representative of each party may be present. An alternative sound-level test code or procedure may be proposed by the Contractor for approval by NASA LeRC.

OPT. A post-installation verification test will be performed by the Purchaser. The test will be conducted in accordance with NASA LeRC post-installation field verification test procedures.

NASA LeRC reserves the right to waive pre-installation acceptance tests or post-installation acceptance tests when certified equipment sound-level test data, acceptable to NASA LeRC, are furnished.

NASA LeRC reserves the right to reject any item which, when tested using specified test procedures, does not meet the required limits. If a pre-installation sound-level test has been waived and the equipment exceeds required sound-level limits on field testing, remedial Contractor action will be required.

5.6 Vibration Isolation

Equipment shall be furnished with vibration isolation treatments in accordance with ASHRAE 1995 Applications Guide, Chapter 43, Sound and Vibration Control, Table 42. Equipment not covered in Table 42 shall be provided with, at minimum, ribbed neoprene pads loaded for a static deflection equal to 20% of their rest height. Steel-spring isolators shall be provided with ribbed neoprene pads mounted in series with the springs.

5.7 Contractor Submittal Form

The primary purpose of the Contractor Submittal Form (Page 20) is to obtain information from the Contractor on noise emission from the equipment, and to help identify responsive bidders. Sections 1 through 3 of the Submittal Form are to be completed by the Purchaser; Sections 4 and 5 are to be completed by the Contractor. All of the information on the Submittal Form can be obtained from the worksheet or Schedule A. The computer spreadsheet version of the Worksheet generates a Submittal Form automatically. No user inputs are required.

Section 4 includes a method (based on ANSI S12.16, "Guidelines for the Specification of Noise of New Machinery") that estimates the Sound Level and octave band sound pressure levels at 1 meter from the equipment under installed conditions for comparison to the specified MPSL criterion. The contractor makes no warranty of performance by working this calculation.



NOISE EMISSION CONTRACTOR SUBMITTAL FORM

Rev. 1, November, 1996

Date	
Project	
By	
Sheet	of

Sections 1 through 2 to be completed by Purchaser

1: EQUIPMENT DESIGNATION

BUILDING & AREA

2: RATED POWER OR CAPACITY OF THIS ITEM

Sections 3 through 5 to be completed by Contractor.

A separate Submittal Form is required for each Purchaser-specified loading condition.

3: ROOM CORRECTION TO FREE FIELD CONDITIONS

		Volume	Room Correction
Test Room Volume	Very Small	55 - 140 cu. m.	-7
	Small	140 - 700 cu. m.	-5
	Medium	700 - 7,000 cu. m.	-2
	Large	> 7,000 cu. m.	-1
Free Field Outdoors			0

4: FREE FIELD SOUND LEVEL, CALCULATED FROM CONTRACTOR'S TESTING DATA

4a. Measured Sound Level at 1 meter (dBA SPL)

4b. Octave Band Center Frequency

4c. Octave Band Sound Pressure Level (if available)

4d. Test Code used for SPL measurements

4e. Contractor Test Room Volume

4f. Loading Conditions for this test

4g. Enter Room Correction from Section 3 corresponding to Contractor's Test Room Volume (entered on Line 4e).

4h. Enter the Sum of Line 4a and Line 4g.

The Free Field Sound Level at 1 meter should be less than the Purchaser's specified MPSL, (Max. Permissible Sound Level, dBA)

4i. Add Line 4g to all columns of Line 4c.

This is the expected octave band sound pressure level under free-field conditions.

5: SOUND POWER LEVEL (FOR OUTDOOR-SITED EQUIPMENT ONLY)

5a. Measured A-wt. Sound Power Level (dBA PWL)

5b. Octave Band Center Frequency

5c. Octave Band Sound Power Level

5d. Test Code used for PWL measurements

5e. Contractor's Test Room Volume

The Sound Power Level spectrum should be less in each octave band than the Purchaser's Maximum Permissible PWL spectrum

APPENDIX A DEFINITIONS OF ACOUSTICAL TERMS

A-weighting - an electrical filter network used by sound level meters, whose output simulates the response of the human ear to low-level sounds. The A-weighting metric also has a strong statistical correlation to noise-induced hearing loss.

A-weighted sound pressure level - an overall sound pressure level reading obtained from a sound level meter by filtering the sound with the A-weighting filter. This term is interchangeable with "sound level".

background noise - noise from all sources unrelated to a particular sound that is the object of interest. Background noise may include airborne, structureborne, and instrument noise.

decibel, dB - the term used to identify ten times the common logarithm of the ratio of two like quantities proportional to power or energy. Thus, one decibel corresponds to a power ratio of 10, and N decibels corresponds to a power ratio of $10^{N/10}$.

NOTE - Since the decibel expresses the ratio of two like quantities, it has no dimensions. It is, however, common practice to treat 'decibel' as a unit as, for example, in the sentence, "The average sound pressure level in the room is 45 decibels."

equivalent sound pressure level, L_{eq} - the level of constant sound pressure level that has the same overall energy content (integrated over the measurement period) as the fluctuating measured signal.

frequency, f [Hz] - the number of sound pressure fluctuations occurring per second due to the presence of a sound wave.

NOTE - a sound may be composed of many frequencies (see spectrum)

insertion loss, IL - of a sound-reducing element, in a specified frequency band. The decrease in sound pressure level, measured at the location of the receiver, where a sound insulator or a sound attenuator is inserted in the transmission path between the source and the receiver. The quantity so obtained is expressed in decibels. Insertion Loss is a meaningful descriptor only when measured in the absence of significant background noise.

maximum permissible sound level (MPSL) - The sound level which may not be exceeded at a distance of 1 meter from equipment specified according to this guide.

octave band - a frequency band which covers a complete musical octave. The ratio of the frequency of the higher band edge to the lower band edge is 2:1. Octave bands are named by their center frequency. Preferred octave bands of interest in this document are 63 Hz, 125 Hz, 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz, 8000 Hz.

PWL - for the purposes of this guide, PWL refers to octave band sound power levels.

reverberant sound - the sound in an enclosed or partially enclosed space that has been reflected repeatedly from the boundaries.

reverberant environment - for the purposes of this guide, an environment is reverberant if it is enclosed by at least two man-made surfaces and has a Room Constant of 100 square meters or less. Calculation of the room constant is beyond the scope of this guide. A simplified graphical method for comparing sound-absorptive and sound-reflective surface areas is presented in Section 3.2f and in Schedule A of the Noise Emission Worksheet for New Equipment.

reverberation - (1) the process and property of the persistence of sound in an enclosed or partially enclosed space after the source of sound has stopped. (2) the buildup of the reflected sound energy within the space, manifested as increased sound pressure levels.

sound absorption - (1) the process of dissipating sound energy. (2) the property possessed by materials, objects and structures such as rooms of absorbing sound energy, expressed as sabins for objects or unit absorbers, and sound absorption coefficient for extended surfaces.

NOTE - Sound energy passing through a wall or opening is regarded as being absorbed in calculations under this guide.

sound absorption coefficient, α ; [dimensionless]; of a surface, in a specified frequency band, the magnitude of the fraction of sound energy striking a material or an object which is absorbed or otherwise not reflected (e.g., sound traveling out through an open window). The sound absorption coefficient is calculated by dividing the sound absorption (in sabins) by the plan area (in square meters) of the test article according to ASTM Test Method C423.

sound-isolating enclosure - any structure that houses the equipment under consideration, and provides significant acoustical isolation. Specific requirements for sound-isolating enclosures related to the use of this guide are given in Section 3.2f (Page 10).

sound level - A-weighted sound pressure level.

sound power level (PWL), of airborne sound, ten times the common logarithm of the ratio of the sound power under consideration to the standard reference power of 1 pW. The quantity so obtained is expressed in decibels.

sound pressure, a fluctuating pressure superimposed on atmospheric pressure by the presence of sound. In analogy with alternating voltage its magnitude can be expressed in several ways, such as instantaneous sound pressure or peak sound pressure, but the

unqualified term means root-mean-square sound pressure. In air, the static pressure is barometric pressure.

sound pressure level (SPL), of airborne sound, ten times the common logarithm of the ratio of the square of the sound pressure under consideration to the square of the standard reference pressure of 20 μPa . The quantity so obtained is expressed in decibels.

NOTE - The pressures are squared because pressure squared, rather than pressure, is proportional to power or energy.

sound transmission class (STC), a rank order classification assigned to partitions, doors, windows and other sound isolating elements to describe their ability to isolate certain sounds. Higher values indicate more effective sound isolation. The classification is effective for sound spectra dominated by high frequencies (500 to 8000 Hz), but may be misleading for sound spectra dominated by low frequencies (31.5 Hz to 250 Hz).

spectrum - the distribution of sound energy across octave bands.

SPL - For the purposes of this guide, SPL refers to octave band sound pressure levels.

test code - a document, issued by a code organization, an engineering organization, or manufacturers' group, which specifies the method of test for a definable class of equipment. Specialized guidance for reporting sound pressure level or sound power level, reference to a basic test standard, and required operating conditions for the equipment under test are typically provided.

test standard - the general method by which tests are conducted to measure fundamental quantities. Topics usually include requirements for equipment, test environment, measurement locations, and expected accuracy.

vibration isolation - reduction, attained by the use of a resilient coupling or mount, in the capacity of a system to vibrate in response to mechanical excitation or to transmit vibration.

APPENDIX B: AIRBORNE SOUND LEVELS FOR TRANSFORMERS

Tables O-2, O-3 and O-4 on Pages 25 and 26 provide typical sound levels from standard electrical transformer equipment, and are reprinted from NEMA TR-1 1993 by the permission of The National Electrical Manufacturers Association. Standard transformers have sound levels ranging from slightly above the maximum permitted by the NEMA standard to as much as 5 to 6 dBA below the maximum permitted. "Quiet" transformers incorporate various forms of noise control and may be up to 25 dBA below the NEMA standard.

Transformers, even with very high MVA ratings, are relatively quiet devices from a hearing-conservation perspective. It is nevertheless strongly recommended that the NEMA standard tables for noise emission be used to encourage good design and manufacturing practices. There is normally no additional cost associated with specifying these levels.

The character of transformer noise is far more objectionable than the A-weighted level might suggest: the acoustic power is concentrated into a small number of very prominent tones. For indoor installations where personnel are present consideration should be given to specifying 10 to 20 dBA below NEMA levels. For outdoor installations where passersby are common, consideration should be given to specifying 10 dBA below NEMA levels. The cost impact of additional quieting is roughly 1% of the transformer cost for reduction of 10 dBA, and 2% for reductions of 20 dBA.

Table 0-2
AUDIBLE SOUND LEVELS FOR OIL-IMMERSED POWER TRANSFORMERS

Column 1 - Class OA, On and FOW Ratings

Column 2 - Class FA and FOA First-stage Auxiliary Cooling**†

Column 3 - Straight FOA Ratings, FA FOA Second-stage Auxiliary Cooling†

Average Sound Level ††, Decibels	Equivalent Two-winding Rating ^Δ																	
	350 kV BIL and Below			450, 550, 650 kV BIL			750 and 825 kV BIL			900 and 1050 kV BIL			1175 kV BIL			1300 kV BIL and Above		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
57	700	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
58	1000	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
59	...	...	...	700	...	...	...	...	...	...	...	...	...	...	...	...	...	...
60	1500	...	...	1000	...	...	...	...	...	...	...	...	...	...	...	...	...	...
61	2000	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
62	2500	...	...	1500	...	...	...	...	...	...	...	...	...	...	...	...	...	...
63	3000	...	...	2000	...	...	...	...	...	...	...	...	...	...	...	...	...	...
64	4000	...	...	2500	...	...	...	...	...	...	...	...	...	...	...	...	...	...
65	5000	...	...	3000	...	...	...	...	...	...	...	...	...	...	...	...	...	...
66	6000	...	...	4000	...	...	3000	...	...	...	...	...	...	...	...	...	...	...
67	7500	8250▲▲	...	5000	3750▲▲	...	4000	3125▲▲	...	...	...	...	...	...	...	...	...	...
68	10000	7500	...	6000	5000	...	5000	3750	...	...	...	...	...	...	...	...	...	...
69	12500	9375	...	7500	6250	...	6000	5000	...	...	...	...	...	...	...	...	...	...
70	15000	12500	...	10000	7500	...	7500	6250	...	...	...	...	...	...	...	...	...	...
71	20000	16667	...	12500	9375	...	10000	7500	...	...	...	...	...	...	...	...	...	...
72	25000	20000	20800	15000	12500	...	12500	9375	...	...	...	...	...	...	...	...	...	...
73	30000	26667	25000	20000	16667	...	15000	12500	...	12500	...	...	...	...	...	...	...	...
74	40000	33333	33333	25000	20000	20800	20000	16667	...	15000	...	...	12500	...	...	...	...	...
75	50000	40000	41667	30000	26667	25000	25000	20000	20800	20000	16667	...	15000	...	...	12500	...	...
76	60000	53333	50000	40000	33333	33333	30000	26667	25000	25000	20000	20800	20000	16667	...	15000	...	...
77	80000	66667	66667	50000	40000	41667	40000	33333	33333	30000	26667	25000	25000	20000	20800	20000	16667	...
78	100000	80000	83333	60000	53333	50000	50000	40000	41667	40000	33333	33333	30000	26667	25000	25000	20000	20800
79	...	106667	100000	80000	66667	66667	60000	53333	50000	50000	40000	40000	33333	33333	30000	26667	25000	...
80	...	133333	133333	100000	80000	83333	80000	66667	66667	60000	53333	50000	50000	40000	41667	40000	33333	33333
81	...	...	166667	...	106667	100000	100000	80000	83333	80000	66667	66667	60000	53333	50000	50000	40000	41667
82	...	...	200000	...	133333	133333	...	106667	100000	100000	80000	83333	80000	66667	66667	60000	53333	50000
83	...	...	250000	...	166667	166667	...	133333	133333	...	106667	100000	100000	80000	83333	80000	66667	66667
84	...	...	300000	...	...	200000	...	166667	...	...	133333	133333	...	106667	100000	100000	80000	83333
85	...	...	400000	...	...	250000	...	200000	...	...	166667	...	133333	133333	...	106667	100000	...
86	...	...	...	...	...	300000	...	250000	...	...	200000	...	...	166667	...	133333	133333	...
87	...	...	...	...	...	400000	...	300000	...	...	250000	...	...	200000	...	...	...	166667
88	...	...	...	...	...	...	...	400000	...	...	...	...	...	250000	...	...	...	200000
89	...	...	...	...	...	...	...	...	...	...	400000	...	...	...	...	...	...	250000
90	...	...	...	...	...	...	...	...	...	...	...	...	...	400000	...	...	...	300000
91	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	400000

*Classes of cooling (see 2.8.1 of American National Standard C57.12.00-1988).

**First- and second-stage auxiliary cooling (see TR 1.0.02).

†For column 2 and 3 ratings, the sound levels are with the auxiliary cooling equipment in operation.

††For intermediate kVA ratings, use the average sound level of the next larger kVA rating.

ΔThe equivalent two-winding 55°C or 65°C rating is defined as one-half the sum of the kVA rating of all windings.

▲▲Sixty-seven decibels for all kVA ratings equal to this or smaller.

Table 0-3
AUDIBLE SOUND LEVELS FOR LIQUID-IMMERSED
DISTRIBUTION TRANSFORMERS AND NETWORK TRANSFORMERS

Equivalent Two-winding kVA	Average Sound Level, Decibels
0-50	48
51-100	51
101-300	55
301-500	56
750	57
1000	58
1500	60
2000	61
2500	62

Table 0-4
AUDIBLE SOUND LEVELS FOR DRY-TYPE TRANSFORMERS 15000-VOLT
NOMINAL SYSTEM VOLTAGE AND BELOW

Equivalent Two-Winding kVA	Average Sound Level, Decibels		Equivalent Two-winding kVA	Average Sound Level, Decibels Ventilated Forced Air Cooled **,†
	Self-cooled Ventilated*	Self-cooled Sealed*		
0-50	50	50	...	...
51-150	55	55	...	...
151-300	58	57	3-300	67
301-500	60	59	301-500	67
501-700	62	61	501-833	67
701-1000	64	63	834-1167	67
1001-1500	65	64	1168-1667	68
1501-2000	66	65	1668-2000	69
2001-3000	68	66	2001-3333	71
3001-4000	70	68	3334-5000	73
4001-5000	71	69	5001-6667	74
5001-6000	72	70	6668-8333	75
6001-7500	73	71	8334-10000	76

* Class AA rating

**Does not apply to sealed-type transformers.

†Class FA and AFA ratings

© reprinted from NEMA TR-1-1993 by permission of the National Electrical Manufacturers Association.

APPENDIX C: EXAMPLES OF COMPLETED WORKSHEETS**C.1 Steam Vent to Atmosphere, Outdoors in Reverberant Courtyard**

"A steam vent is located outdoors in a walled courtyard measuring 10 by 10 by 15 meters high, and is located more than 3 meters from personnel, passersby, and other noise emitting equipment."

Assume that the four walls of the courtyard consist of the exterior walls of adjacent buildings on all four sides, and have no sound absorption treatments applied to them. A +5 dBA adjustment is applied because the site is outdoors and remote. The calculation in Schedule A indicates that the courtyard, even though outdoors, is deemed to be reverberant for the purposes of this guide.

The MPSL calculation is summarized below. The Steam Vent belongs to Group 2 (85 dBA); no adjustments are allowed for the intermittent operation of the equipment.

Group 2	85
Unattended Sound-Isolating Enclosure	0
Control Room and Sound-Isolating Enclosure	0
Outdoor Site	+5
Infrequent Operation	0
Intermittent Operation	0
Reverberant Environment	-5
<u>Equipment Density</u>	<u>0</u>
MPSL (dBA)	85

In addition, equipment noise must be less than the maximum permissible PWL spectrum for outdoor equipment.



NOISE EMISSION WORKSHEET FOR NEW EQUIPMENT

Rev. 1, November, 1996

to be used in conjunction with NASA LeRC "Guide for Specifying Equipment Noise Emission Levels"

Date	12/1/96
Project	Appendix C-1: Outdoor Steam Vent
By	DAN
Sheet	1 of 2

1: ITEM DESIGNATION BUILDING & AREA

Steam Vent in Outdoor Courtyard
Building 999

2: RATED POWER OR CAPACITY OF EQUIPMENT (with units)

	Units
--	-------

3: IS THE ITEM WITHIN THE SCOPE OF THE DOCUMENT? (Click boxes as appropriate)

3a: Is the mechanical power of this item less than 3000 HP (2,238 kW)?

OR

Is the cooling capacity of this item less than 500 Tons (60 MJ/hr)?

<input checked="" type="checkbox"/>	Yes
<input type="checkbox"/>	No

3b: Is the equipment to be installed in a ground floor location?

Please Continue

4: EQUIPMENT GROUP (See Section 2, Table 1)

4a: Enter number of Equipment Group

2

Group 1: Heavy Machinery

Group 2: Vents to Atmosphere

Group 3: Piping and Ductwork

Group 4: Light Machinery

Group 5: Transformers

5: BASELINE MAXIMUM PERMISSIBLE LEVELS

5a: Baseline Maximum Permissible Sound Level (dBA)

For Equipment Group Number 1 or 2, enter 85

For Equipment Group 3 or 4, enter 80

For Equipment Group 5, refer to NEMA TR-1 (Values Tabulated in Appendix B)

85

and Stop here.

6: ADJUSTMENTS FOR GROUPS 1, 2, 3 and 4

For each case that applies, click in the corresponding box	Yes/No	Adjust ^t	Column 1
6a. Unattended Sound-Isolating Equipment Enclosure: If "No", Skip to 6c	<input checked="" type="checkbox"/> No	20	0
6b. Control Room and Sound-Isolating Enclosure	<input checked="" type="checkbox"/> No	-10	0
6c. Remote Outdoor Site: no personnel within 3 meters	<input type="checkbox"/> Yes	5	5
6d. Infrequent Operation: operates during fewer than 15 8-hr. shifts per year	<input type="checkbox"/> No	5	0
6e. Intermittent Operation: < 30 min./shift, < 6 time/hr. Not for use with Group 2	<input type="checkbox"/> No	5 ^a	0
6f. Reverberant Environment: imported from Line A5 of Schedule A	<input type="checkbox"/> Yes	-5	-5
6g. High Equipment Density: more than 5 pieces of equipment within a 3-meter radius	<input type="checkbox"/> No	-5	0

7: MAXIMUM PERMISSIBLE SOUND LEVEL AT 1 METER

7a: Sum applicable adjustments in Column 1

0

7b: Limit Credit to 25 dB: The lesser of 25 and Line 7a

0

7c: Maximum Permissible Sound Level (MPSL): Add Line 5a and Line 7b >>>>

85

8: MAXIMUM PERMISSIBLE OCTAVE BAND SOUND POWER LEVELS FOR OUTDOOR EQUIPMENT

8a: Is the Equipment Sited Outdoors?

Yes

(Note - This section applies to unenclosed outdoor equipment and to equipment with contractor-supplied enclosures)

8b: Max. Permissible PWL if Outdoors

8c: For Outdoor Equipment, Copy Line 8b

63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
127	120	113	110	108	107	107	106
127	120	113	110	108	107	107	106



NOISE EMISSION WORKSHEET FOR NEW EQUIPMENT

Rev. 1, November, 1996

to be used in conjunction with NASA LeRC "Guide for Specifying Equipment Noise Emission Levels"

Date	12/1/96
Project	Appendix C-1: Outdoor Steam Vent
By	DAN
Sheet	1 of 1

SCHEDULE A: INSTALLED ENVIRONMENT

A1: Approximate Volume of Host Space or Sound-Isolating Enclosure
Click in the appropriate box (for use in Contractor Submittal Sheet)

Volume Designation	Very Small	Small	Medium	Large	Free Field
Cubic Meters	55 - 140	140 - 700	700 - 7,000	> 7,000	Outdoors
Click appropriate box	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

A2: Tabulate Sound-Absorptive and Sound-Reflective Areas in Square Meters
(Note - If Outdoors with no reflecting surfaces, use Absorbing Area = 200 sq. m.)

Designation	Col. 1	Col. 2
	Absorbing Area (sq. m.)	Reflective Area (sq. m.)
Ground		100
Solid Wall		150
Solid Wall		150
Solid Wall		150
Solid Wall		150
Sky	100	

Sound-Absorbing Materials	
Glass Fiber	50 mm or thicker
Mineral Fiber	50 mm or thicker
Basalt Wool	50 mm or thicker
Open-Cell Foams	75 mm or thicker
Tectum on 40 mm airspace	50 mm or thicker
Acoustical Ceiling Tile	on 400 mm airspace
Hanging Acoustical Baffles	50 mm or thicker
Sky, Open Doors & Windows	
Sound-Reflective Materials	
Brick, Stone, Concrete	
Wood, Glass, Metal	
Tile, Plaster	
Gypsum Board	
Closed-Cell Foams	
Ground	

A3: Total Absorptive Area (Col. 1)

100

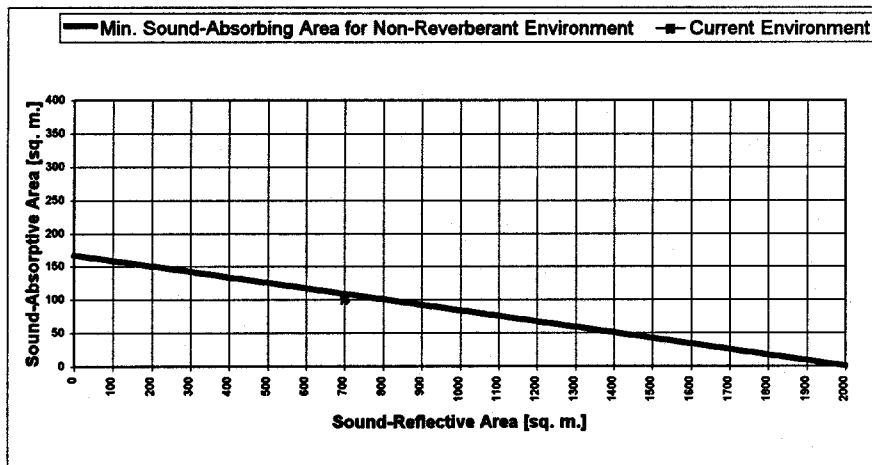
A4: Total Reflective Area (Col. 2)

700

LOCATE THE POINT ON THE GRAPH CORRESPONDING TO THIS COMBINATION.
IF THE POINT IS BELOW THE LINE, THE ENVIRONMENT IS REVERBERANT.
IF THE POINT IS ABOVE THE LINE, THE ENVIRONMENT IS NON-REVERBERANT.

A5: If Reverberant, Enter "Yes" here and -5 in Col. 1 of Worksht. Line 6f

Yes



Appendix C.2: Centrifugal Chiller in Unattended Acoustical Enclosure, Infrequent Operation

"A 300T centrifugal chiller is located inside an unattended enclosure that meets the requirements of Section 3.2f, inside a larger building. The unit operates in support of a process which occurs for an 8-hour period, 12 times per year. During operation, noise emission is continuous. The enclosure measures 10 × 13 × 8 meters high and is covered on its ceiling and half of its wall surfaces with 3-in. thick glass fiber, exposed to the sound field.

The chiller shares the enclosure with more than five other noise-producing equipment items which are located within a 3-meter radius of the chiller."

The MPSL calculation is summarized below.

Group 1	85
Unattended Sound-Isolating Enclosure	+20
Control Room and Sound-Isolating Enclosure	0
Outdoor Site	0
Infrequent Operation	+5
Intermittent Operation	0
Reverberant Environment	0
<u>Equipment Density</u>	<u>-5</u>
MPSL (dBA)	105



NOISE EMISSION WORKSHEET FOR NEW EQUIPMENT

Rev. 1, November, 1996

to be used in conjunction with NASA LeRC "Guide for Specifying Equipment Noise Emission Levels"

Date	12/1/96
Project	Appendix C-2: 300T Chiller in Enclosure
By	DAN
Sheet	1 of 2

1: ITEM DESIGNATION BUILDING & AREA

300T Centrifugal Chiller in Sound-Isolating Enclosure
Building 999

2: RATED POWER OR CAPACITY OF EQUIPMENT (with units)

300	Tons
-----	------

3: IS THE ITEM WITHIN THE SCOPE OF THE DOCUMENT? (Click boxes as appropriate)

3a: Is the mechanical power of this item less than 3000 HP (2,238 kW)?

OR

Is the cooling capacity of this item less than 500 Tons (60 MJ/hr)?

<input checked="" type="checkbox"/>	Yes
<input type="checkbox"/>	No

3b: Is the equipment to be installed in a ground floor location?

<input checked="" type="checkbox"/>	Yes
<input type="checkbox"/>	No

Please Continue

4: EQUIPMENT GROUP (See Section 2, Table 1)

4a: Enter number of Equipment Group

1

Group 1: Heavy Machinery

Group 2: Vents to Atmosphere

Group 3: Piping and Ductwork

Group 4: Light Machinery

Group 5: Transformers

5: BASELINE MAXIMUM PERMISSIBLE LEVELS

5a: Baseline Maximum Permissible Sound Level (dBA)

For Equipment Group Number 1 or 2, enter 85

For Equipment Group 3 or 4, enter 80

For Equipment Group 5, refer to NEMA TR-1 (Values Tabulated in Appendix B) and Stop here.

85

6: ADJUSTMENTS FOR GROUPS 1, 2, 3 and 4

For each case that applies, click in the corresponding box

	Yes/No	Adjust't	Column 1
6a. Unattended Sound-Isolating Equipment Enclosure: If "No", Skip to 6c	<input checked="" type="checkbox"/> Yes	20	20
6b. Control Room and Sound-Isolating Enclosure	<input type="checkbox"/> No	-10	0
6c. Remote Outdoor Site: no personnel within 3 meters	<input type="checkbox"/> No	5	0
6d. Infrequent Operation: operates during fewer than 15 8-hr. shifts per year	<input checked="" type="checkbox"/> Yes	5	5
6e. Intermittent Operation: < 30 min./shift, < 6 time/hr. Not for use with Group 2	<input type="checkbox"/> No	5*	0
6f. Reverberant Environment: Imported from Line A5 of Schedule A	<input type="checkbox"/> No	-5	0
6g. High Equipment Density: more than 5 pieces of equipment within a 3-meter radius	<input checked="" type="checkbox"/> Yes	-5	-5

7: MAXIMUM PERMISSIBLE SOUND LEVEL AT 1 METER

7a: Sum applicable adjustments in Column 1

20
20

7b: Limit Credit to 25 dB: The lesser of 25 and Line 7a

7c: Maximum Permissible Sound Level (MPSL): Add Line 5a and Line 7b >>>>

105

8: MAXIMUM PERMISSIBLE OCTAVE BAND SOUND POWER LEVELS FOR OUTDOOR EQUIPMENT

8a: Is the Equipment Sited Outdoors?

<input checked="" type="checkbox"/> No
--

(Note - This section applies to unenclosed outdoor equipment and to equipment with contractor-supplied enclosures)

8b: Max. Permissible PWL If Outdoors

8c: For Outdoor Equipment, Copy Line 8b

63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
127	120	113	110	108	107	107	106
XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX



NOISE EMISSION WORKSHEET FOR NEW EQUIPMENT

Rev. 1, November, 1996

to be used in conjunction with NASA LeRC "Guide for Specifying Equipment Noise Emission Levels"

Date	12/1/96
Project	Appendix C-2: 300T Chiller in Enclosure
By	DAN
Sheet	1 of 1

SCHEDULE A: INSTALLED ENVIRONMENT

A1: Approximate Volume of Host Space or Sound-Isolating Enclosure

Click in the appropriate box (for use in Contractor Submittal Sheet)

Volume Designation	Very Small	Small	Medium	Large	Free Field
Cubic Meters	55 - 140	140 - 700	700 - 7,000	> 7,000	Outdoors
Click appropriate box	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

A2: Tabulate Sound-Absorptive and Sound-Reflective Areas in Square Meters

(Note - If Outdoors with no reflecting surfaces, use Absorbing Area = 200 sq. m.)

Designation	Col. 1	Col. 2
	Absorbing Area (sq. m.)	Reflective Area (sq. m.)
Floor		130
Wall 1	40	40
Wall 2	52	52
Wall 3	40	40
Wall 4	52	52
Ceiling	130	

Sound-Absorbing Materials	
Glass Fiber	50 mm or thicker
Mineral Fiber	50 mm or thicker
Basalt Wool	50 mm or thicker
Open-Cell Foams	75 mm or thicker
Tectum on 40 mm airspace	50 mm or thicker
Acoustical Ceiling Tile	on 400 mm airspace
Hanging Acoustical Baffles	50 mm or thicker
Sky, Open Doors & Windows	
Sound-Reflective Materials	
Brick, Stone, Concrete	
Wood, Glass, Metal	
Tile, Plaster	
Gypsum Board	
Closed-Cell Foams	
Ground	

A3: Total Absorptive Area (Col. 1)

314

A4: Total Reflective Area (Col. 2)

314

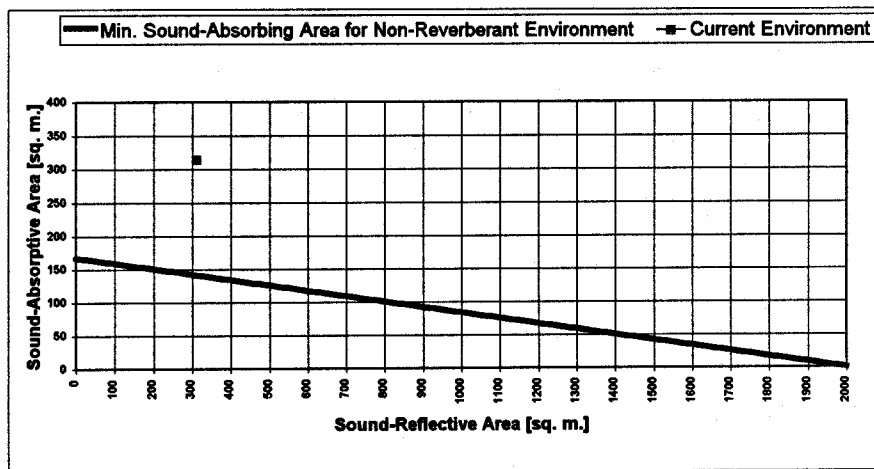
LOCATE THE POINT ON THE GRAPH CORRESPONDING TO THIS COMBINATION.

IF THE POINT IS BELOW THE LINE, THE ENVIRONMENT IS REVERBERANT.

IF THE POINT IS ABOVE THE LINE, THE ENVIRONMENT IS NON-REVERBERANT.

A5: If Reverberant, Enter "Yes" here and -5 in Col. 1 of Worksht. Line 6f

No



Appendix C.3: Air Compressor (Intermittent Operation)

"A 25 HP air compressor is located indoors in Building 64 (dimensions: 50 by 50 meters by 15 meters high), operating daily, two to three times per hour for a few minutes each time. The compressor is located more than 3 meters away from other noise producing equipment."

The MPSL calculation is summarized below. The Air Compressor could be considered either a Group 1 or Group 4 (80 dBA) item. Group 4 will be used for this example. Note that, owing to its large size, Building 64 is deemed to be non-reverberant for the purposes of this standard, even though no sound absorbing material has been assumed to be present.

Group 4	80
Unattended Sound-Isolating Enclosure	0
Control Room and Sound-Isolating Enclosure	0
Outdoor Site	0
Infrequent Operation	0
Intermittent Operation	+ 5
Reverberant Environment	0
<u>Equipment Density</u>	<u>0</u>
MPSL (dBA)	85

26 November, 1996

NASA LeRC Guide for Specifying Equipment Noise Emission Levels


**NOISE EMISSION
WORKSHEET FOR
NEW EQUIPMENT**

Rev. 1, November, 1996

Date	12/1/96
Project	Appendix C-3: 25 HP Air Compressor
By	DAN
Sheet	1 of 2

to be used in conjunction with NASA LeRC "Guide for Specifying Equipment Noise Emission Levels"

**1: ITEM DESIGNATION
BUILDING & AREA**

25 HP Air Compressor
Building 64

2: RATED POWER OR CAPACITY OF EQUIPMENT (with units)

25	HP
----	----

3: IS THE ITEM WITHIN THE SCOPE OF THE DOCUMENT? (Click boxes as appropriate)

3a: Is the mechanical power of this item less than 3000 HP (2,238 kW)?

OR

Is the cooling capacity of this item less than 500 Tons (60 MJ/hr)?

<input checked="" type="checkbox"/>	Yes
<input checked="" type="checkbox"/>	Yes

3b: Is the equipment to be installed in a ground floor location?

Please Continue

4: EQUIPMENT GROUP (See Section 2, Table 1)

4a: Enter number of Equipment Group

4

Group 1: Heavy Machinery

Group 2: Vents to Atmosphere

Group 3: Piping and Ductwork

Group 4: Light Machinery

Group 5: Transformers

2500

5: BASELINE MAXIMUM PERMISSIBLE LEVEL

750

5a: Baseline Maximum Permissible

750

For Equipment Group Number 1 or

750

For Equipment Group 3 or 4, enter

750

For Equipment Group 5, refer to N

2500

80

and Stop here.

6: ADJUSTMENTS FOR GROUPS 1, 2, 3 and 4

For each case that applies, click in the corresponding box	Yes/No	Adjust't	Column 1
6a. Unattended Sound-Isolating Equipment Enclosure: if "No", Skip to 6c	<input checked="" type="checkbox"/> No	20	0
6b. Control Room and Sound-Isolating Enclosure	<input checked="" type="checkbox"/> No	-10	0
6c. Remote Outdoor Site: no personnel within 3 meters	<input checked="" type="checkbox"/> No	5	0
6d. Infrequent Operation: operates during fewer than 15 8-hr. shifts per year	<input checked="" type="checkbox"/> No	5	0
6e. Intermittent Operation: < 30 min./shift, < 6 time/hr. Not for use with Group 2	<input checked="" type="checkbox"/> Yes	5*	5
6f. Reverberant Environment: imported from Line A5 of Schedule A	<input checked="" type="checkbox"/> No	-5	0
6g. High Equipment Density: more than 5 pieces of equipment within a 3-meter radius	<input checked="" type="checkbox"/> No	-5	0

7: MAXIMUM PERMISSIBLE SOUND LEVEL AT 1 METER

7a: Sum applicable adjustments in Column 1

5

7b: Limit Credit to 25 dB: The lesser of 25 and Line 7a

5

7c: Maximum Permissible Sound Level (MPSL): Add Line 5a and Line 7b >>>>

85

8: MAXIMUM PERMISSIBLE OCTAVE BAND SOUND POWER LEVELS FOR OUTDOOR EQUIPMENT

8a: Is the Equipment Sited Outdoors?

<input checked="" type="checkbox"/> No
--

(Note - This section applies to unenclosed outdoor equipment and to equipment with contractor-supplied enclosures)

8b: Max. Permissible PWL if Outdoors

8c: For Outdoor Equipment, Copy Line 8b

63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
127	120	113	110	108	107	107	106
XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX



NOISE EMISSION WORKSHEET FOR NEW EQUIPMENT

Rev. 1, November, 1996

to be used in conjunction with NASA LeRC "Guide for Specifying Equipment Noise Emission Levels"

25 HP Air Compressor
Building 64

SCHEDULE A: INSTALLED ENVIR

A1: Approximate Volume of Host Space or Sound-Isolating Enclosure

Click in the appropriate box (for use in Contractor Submittal Sheet)

Volume Designation	Very Small	Small	Medium	Large	Free Field
Cubic Meters	55 - 140	140 - 700	700 - 7,000	> 7,000	Outdoors
Click appropriate box	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

A2: Tabulate Sound-Absorptive and Sound-Reflective Areas in Square Meters

(Note - If Outdoors with no reflecting surfaces, use Absorbing Area = 200 sq. m.)

Designation	Col. 1 Absorbing Area (sq. m.)	Col. 2 Reflective Area (sq. m.)
Floor		2500
Wall 1		750
Wall 2		750
Wall 3		750
Wall 4		750
Ceiling		2500
6b. Control Room and Sound-Isolating Enclosure		

Sound-Absorbing Materials

Glass Fiber	50 mm or thicker
Mineral Fiber	50 mm or thicker
Basalt Wool	50 mm or thicker
Open-Cell Foams	75 mm or thicker
Tectum on 40 mm airspace	50 mm or thicker
Acoustical Ceiling Tile	on 400 mm airspace
Hanging Acoustical Baffles	50 mm or thicker
Sky, Open Doors & Windows	

Sound-Reflective Materials

Brick, Stone, Concrete
Wood, Glass, Metal
Tile, Plaster
Gypsum Board
Closed-Cell Foams
Ground

A3: Total Absorptive Area (Col. 1)

0

6g. High Equipment Density: more than 5 pieces of equipment

8000

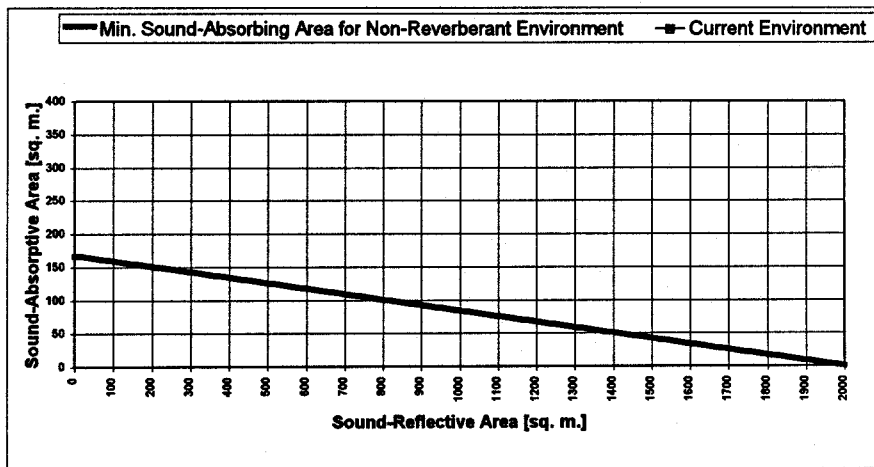
LOCATE THE POINT ON THE GRAPH CORRESPONDING TO THIS COMBINATION.

IF THE POINT IS BELOW THE LINE, THE ENVIRONMENT IS REVERBERANT.

IF THE POINT IS ABOVE THE LINE, THE ENVIRONMENT IS NON-REVERBERANT.

A5: If Reverberant, Enter "Yes" here and -5 in Col. 1 of Worksht. Line 6f

No



Appendix C.4: Large Exhauster in Dedicated Sound-Isolating Building with Control Room

"An exhauster with 5000 HP drive motor is to be installed in a dedicated sound-isolating building. A free-standing sound-isolating enclosure inside the building serves as a control room. The building is located more than 3 meters from areas frequented by personnel or passersby."

The mechanical power of the exhauster is large enough to be outside of the scope of this guide. Assistance should be requested from NEMP for evaluating the noise impact of such an installation. The worksheet should nevertheless be completed in order to provide information to NEMP.

The sound-isolating building is considered unattended because no operators are present outside the control room during operation. The control room is itself a sound-isolating enclosure, and is exposed to the sound field inside the sound isolating building. Thus the "Control Room" adjustment applies.

The MPSL calculation is summarized below.

Group 1	85
Unattended Sound-Isolating Enclosure	+ 20
Control Room and Sound-Isolating Enclosure	-10
Outdoor Site	+5
Infrequent Operation	0
Intermittent Operation	0
Reverberant Environment	0
<u>Equipment Density</u>	<u>0</u>
MPSL (dBA)	100

Because the sound-isolating building is supplied by others, the PWL specification in its present form cannot be applied to the equipment located inside the building.



NOISE EMISSION WORKSHEET FOR NEW EQUIPMENT

Rev. 1, November, 1996

Date	12/1/96
Project	Appendix C-4: Large Exhauster
By	DAN
Sheet	1 of 2

to be used in conjunction with NASA LeRC "Guide for Specifying Equipment Noise Emission Levels"

1: ITEM DESIGNATION BUILDING & AREA

Exhauster, Sound-Isolating Enclosure, Outdoors
Building 999

2: RATED POWER OR CAPACITY OF EQUIPMENT (with units)

5000	HP
------	----

3: IS THE ITEM WITHIN THE SCOPE OF THE DOCUMENT? (Click boxes as appropriate)

3a: Is the mechanical power of this item less than 3000 HP (2,238 kW)?

OR

Is the cooling capacity of this item less than 500 Tons (60 MJ/hr)?

<input type="checkbox"/>	No
<input type="checkbox"/>	Yes

3b: Is the equipment to be installed in a ground floor location?

Please Complete Worksheet and Contact NEM

4: EQUIPMENT GROUP (See Section 2, Table 1)

4a: Enter number of Equipment Group

1

Group 1: Heavy Machinery

Group 2: Vents to Atmosphere

Group 3: Piping and Ductwork

Group 4: Light Machinery

Group 5: Transformers

5: BASELINE MAXIMUM PERMISSIBLE LEVELS

5a: Baseline Maximum Permissible Sound Level (dBA)

For Equipment Group Number 1 or 2, enter 85

For Equipment Group 3 or 4, enter 80

For Equipment Group 5, refer to NEMA TR-1 (Values Tabulated in Appendix B)

85

and Stop here.

6: ADJUSTMENTS FOR GROUPS 1, 2, 3 and 4

For each case that applies, click in the corresponding box	Yes/No	Adjustt	Column 1
6a. Unattended Sound-Isolating Equipment Enclosure: If "No", Skip to 6c	<input type="checkbox"/>	20	20
6b. Control Room and Sound-Isolating Enclosure	<input type="checkbox"/>	-10	-10
6c. Remote Outdoor Site: no personnel within 3 meters	<input type="checkbox"/>	5	5
6d. Infrequent Operation: operates during fewer than 15 8-hr. shifts per year	<input type="checkbox"/>	5	0
6e. Intermittent Operation: < 30 min./shift, < 6 time/hr. Not for use with Group 2	<input type="checkbox"/>	5	0
6f. Reverberant Environment: imported from Line A5 of Schedule A	<input type="checkbox"/>	-5	0
6g. High Equipment Density: more than 5 pieces of equipment within a 3-meter radius	<input type="checkbox"/>	-5	0

7: MAXIMUM PERMISSIBLE SOUND LEVEL AT 1 METER

7a: Sum applicable adjustments in Column 1

7b: Limit Credit to 25 dB: The lesser of 25 and Line 7a

7c: Maximum Permissible Sound Level (MPSL): Add Line 5a and Line 7b >>>>

15
15
100

8: MAXIMUM PERMISSIBLE OCTAVE BAND SOUND POWER LEVELS FOR OUTDOOR EQUIPMENT

8a: Is the Equipment Sited Outdoors?

<input type="checkbox"/>	No
--------------------------	----

(Note - This section applies to unenclosed outdoor equipment and to equipment with contractor-supplied enclosures)

8b: Max. Permissible PWL if Outdoors

8c: For Outdoor Equipment, Copy Line 8b

63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
127	120	113	110	108	107	107	106
XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX



NOISE EMISSION WORKSHEET FOR NEW EQUIPMENT

Rev. 1, November, 1996

to be used in conjunction with NASA LeRC "Guide for Specifying Equipment Noise Emission Levels"

Date	12/1/96
Project	Appendix C-4: Large Exhauster
By	DAN
Sheet	1 of 1

SCHEDULE A: INSTALLED ENVIRONMENT

A1: Approximate Volume of Host Space or Sound-Isolating Enclosure

Click in the appropriate box (for use in Contractor Submittal Sheet)

Volume Designation	Very Small	Small	Medium	Large	Free Field
Cubic Meters	55 - 140	140 - 700	700 - 7,000	> 7,000	Outdoors
Click appropriate box	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

A2: Tabulate Sound-Absorptive and Sound-Reflective Areas in Square Meters

(Note - If Outdoors with no reflecting surfaces, use Absorbing Area = 200 sq. m.)

Designation	Col. 1	Col. 2
	Absorbing Area (sq. m.)	Reflective Area (sq. m.)
Floor		300
Wall 1	150	
Wall 2	200	
Wall 3	150	
Wall 4	200	
Ceiling	300	

Sound-Absorbing Materials	
Glass Fiber	50 mm or thicker
Mineral Fiber	50 mm or thicker
Basalt Wool	50 mm or thicker
Open-Cell Foams	75 mm or thicker
Tectum on 40 mm airspace	50 mm or thicker
Acoustical Ceiling Tile	on 400 mm airspace
Hanging Acoustical Baffles	50 mm or thicker
Sky, Open Doors & Windows	
Sound-Reflective Materials	
Brick, Stone, Concrete	
Wood, Glass, Metal	
Tile, Plaster	
Gypsum Board	
Closed-Cell Foams	
Ground	

A3: Total Absorptive Area (Col. 1)

1000

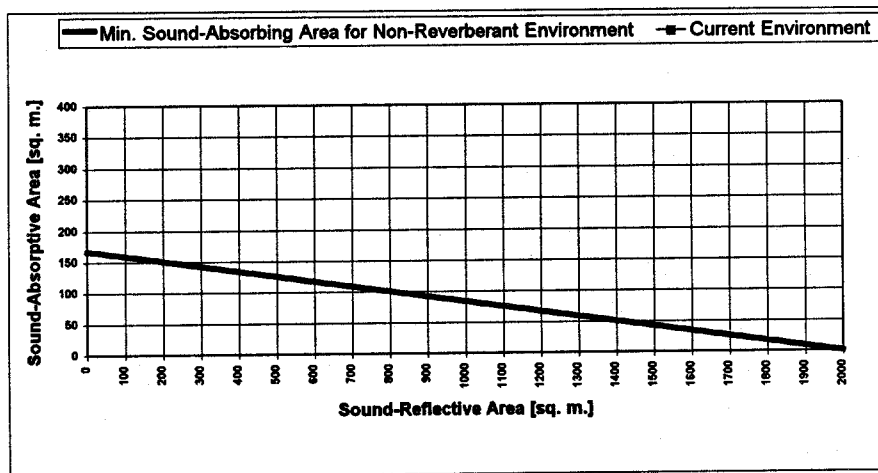
A4: Total Reflective Area (Col. 2)

300

LOCATE THE POINT ON THE GRAPH CORRESPONDING TO THIS COMBINATION.
IF THE POINT IS BELOW THE LINE, THE ENVIRONMENT IS REVERBERANT.
IF THE POINT IS ABOVE THE LINE, THE ENVIRONMENT IS NON-REVERBERANT.

A5: If Reverberant, Enter "Yes" here and -5 in Col. 1 of Worksht. Line 6f

No



Appendix C.5: Ductwork for Large Exhauster

"Ductwork serving the large exhauster described in Appendix C.4 provides process air to other buildings on the laboratory grounds. The ductwork is located outdoors over most of its length, and traverses parking lots and sidewalks. "

The ductwork is radiates airborne and structureborne noise created by the exhauster. At distances more than 3 meters from Group 1 equipment (in this case the Exhauster), the Equipment Group 3 baseline noise emission criterion of 80 dBA applies. None of the adjustments apply in the case at hand, so the MPSL is 80 dBA.

Group 3	80
Unattended Sound-Isolating Enclosure	0
Control Room and Sound-Isolating Enclosure	0
Outdoor Site	0
Infrequent Operation	0
Intermittent Operation	0
Reverberant Environment	0
<u>Equipment Density</u>	<u>0</u>
MPSL (dBA)	80

In addition, because the ductwork is located outdoors, the installation must meet the maximum permissible sound power levels specified in Section 3.3 (Page 12).



NOISE EMISSION WORKSHEET FOR NEW EQUIPMENT

Rev. 1, November, 1996

Date	12/1/96	
Project	Appendix C-5: Large Exhauster Ductwork	
By	DAN	
Sheet	1	of 2

to be used in conjunction with NASA LeRC "Guide for Specifying Equipment Noise Emission Levels"

1: ITEM DESIGNATION BUILDING & AREA

Exhauster Ductwork, Outdoors
Building 999

2: RATED POWER OR CAPACITY OF EQUIPMENT (with units)

5000	HP
------	----

3: IS THE ITEM WITHIN THE SCOPE OF THE DOCUMENT? (Click boxes as appropriate)

3a: Is the mechanical power of this Item less than 3000 HP (2,238 kW)?

OR

Is the cooling capacity of this Item less than 500 Tons (60 MJ/hr)?

<input checked="" type="checkbox"/>	No
<input type="checkbox"/>	Yes

3b: Is the equipment to be installed in a ground floor location?

Please Complete Worksheet and Contact NEM

4: EQUIPMENT GROUP (See Section 2, Table 1)

4a: Enter number of Equipment Group

3

Group 1: Heavy Machinery

Group 2: Vents to Atmosphere

Group 3: Piping and Ductwork

Group 4: Light Machinery

Group 5: Transformers

5: BASELINE MAXIMUM PERMISSIBLE LEVELS

5a: Baseline Maximum Permissible Sound Level (dBA)

For Equipment Group Number 1 or 2, enter 85

For Equipment Group 3 or 4, enter 80

For Equipment Group 5, refer to NEMA TR-1 (Values Tabulated in Appendix B)

and Stop here.

80

6: ADJUSTMENTS FOR GROUPS 1, 2, 3 and 4

For each case that applies, click in the corresponding box	Yes/No	Adjust't	Column 1
6a. Unattended Sound-Isolating Equipment Enclosure: If "No", Skip to 6c	<input checked="" type="checkbox"/> No	20	0
6b. Control Room and Sound-Isolating Enclosure	<input checked="" type="checkbox"/> No	-10	0
6c. Remote Outdoor Site: no personnel within 3 meters	<input checked="" type="checkbox"/> No	5	0
6d. Infrequent Operation: operates during fewer than 15 8-hr. shifts per year	<input checked="" type="checkbox"/> No	5	0
6e. Intermittent Operation: < 30 min./shift, < 6 time/hr; Not for use with Group 2	<input checked="" type="checkbox"/> No	5*	0
6f. Reverberant Environment: imported from Line A5 of Schedule A	<input checked="" type="checkbox"/> No	-5	0
6g. High Equipment Density: more than 5 pieces of equipment within a 3-meter radius	<input checked="" type="checkbox"/> No	-5	0

7: MAXIMUM PERMISSIBLE SOUND LEVEL AT 1 METER

7a: Sum applicable adjustments in Column 1

7b: Limit Credit to 25 dB: The lesser of 25 and Line 7a

7c: Maximum Permissible Sound Level (MPSL): Add Line 5a and Line 7b >>>>

0
0
80

8: MAXIMUM PERMISSIBLE OCTAVE BAND SOUND POWER LEVELS FOR OUTDOOR EQUIPMENT

8a: Is the Equipment Sited Outdoors?

<input checked="" type="checkbox"/> Yes

(Note - This section applies to unenclosed outdoor equipment and to equipment with contractor-supplied enclosures)

	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
8b: Max. Permissible PWL if Outdoors	127	120	113	110	108	107	107	106
8c: For Outdoor Equipment, Copy Line 8b	127	120	113	110	108	107	107	106



Appendix C.6: Diesel-Powered Generator Set with On-Skid Enclosure

"A 300 HP diesel generator set is located outdoors in a field. Equipment controls are accessed by means of acoustically-treated operable panels in the side of the sound-isolating enclosure. The unit is provided with an on-skid enclosure."

The reciprocating engine and generator belong to Group 1. Because the engine, generator and enclosure are typically provided as a package, the equipment is treated as a single item for noise emission specification purposes. The outdoor site is assumed to be remote. Because the enclosure is supplied with the package, it is not appropriate to take the +20 adjustment for the sound-isolating enclosure. The MPSL of 90 dBA refers therefore to sound levels observed outside the enclosure.

Group 1	85
Unattended Sound-Isolating Enclosure	0
Control Room and Sound-Isolating Enclosure	0
Remote Outdoor Site	+5
Infrequent Operation	0
Intermittent Operation	0
Reverberant Environment	0
Equipment Density	0
MPSL (dBA)	90

In addition, because the unit is located outdoors, the installation must meet the maximum permissible sound power levels specified in Section 3.3 (Page 12).

NASA LeRC Guide for Specifying Equipment Noise Emission Levels


**NOISE EMISSION
WORKSHEET FOR
NEW EQUIPMENT**

Rev. 1, November, 1996

Date	12/1/96
Project	Appendix C-6: Diesel GenSet
By	DAN
Sheet	1 of 2

to be used in conjunction with NASA LeRC "Guide for Specifying Equipment Noise Emission Levels"

**1: ITEM DESIGNATION
BUILDING & AREA**

Diesel Generator Set, On-Skid Enclosure, Outdoors
Building 999

2: RATED POWER OR CAPACITY OF EQUIPMENT (with units)

300	HP
-----	----

3: IS THE ITEM WITHIN THE SCOPE OF THE DOCUMENT? (Click boxes as appropriate)

3a: Is the mechanical power of this item less than 3000 HP (2,238 kW)?

OR

Is the cooling capacity of this item less than 500 Tons (60 MJ/hr)?

<input checked="" type="checkbox"/>	Yes
<input checked="" type="checkbox"/>	Yes

3b: Is the equipment to be installed in a ground floor location?

Please Continue

4: EQUIPMENT GROUP (See Section 2, Table 1)

4a: Enter number of Equipment Group

1

Group 1: Heavy Machinery

Group 2: Vents to Atmosphere

Group 3: Piping and Ductwork

Group 4: Light Machinery

Group 5: Transformers

5: BASELINE MAXIMUM PERMISSIBLE LEVELS

5a: Baseline Maximum Permissible Sound Level (dBA)

For Equipment Group Number 1 or 2, enter 85

For Equipment Group 3 or 4, enter 80

For Equipment Group 5, refer to NEMA TR-1 (Values Tabulated in Appendix B)
and Stop here.

85

6: ADJUSTMENTS FOR GROUPS 1, 2, 3 and 4

For each case that applies, click in the corresponding box	Yes/No	Adjust't	Column 1
6a. Unattended Sound-Isolating Equipment Enclosure: If "No", Skip to 6c	<input checked="" type="checkbox"/> No	20	0
6b. Control Room and Sound-Isolating Enclosure	<input checked="" type="checkbox"/> No	-10	0
6c. Remote Outdoor Site: no personnel within 3 meters	<input checked="" type="checkbox"/> Yes	5	5
6d. Infrequent Operation: operates during fewer than 15 8-hr. shifts per year	<input checked="" type="checkbox"/> No	5	0
6e. Intermittent Operation: < 30 min./shift, < 6 time/hr. Not for use with Group 2	<input checked="" type="checkbox"/> No	5*	0
6f. Reverberant Environment: imported from Line A5 of Schedule A	<input checked="" type="checkbox"/> No	-5	0
6g. High Equipment Density: more than 5 pieces of equipment within a 3-meter radius	<input checked="" type="checkbox"/> No	-5	0

7: MAXIMUM PERMISSIBLE SOUND LEVEL AT 1 METER

7a: Sum applicable adjustments in Column 1

7b: Limit Credit to 25 dB: The lesser of 25 and Line 7a

7c: Maximum Permissible Sound Level (MPSL): Add Line 5a and Line 7b >>>>>

5
5
90

8: MAXIMUM PERMISSIBLE OCTAVE BAND SOUND POWER LEVELS FOR OUTDOOR EQUIPMENT

8a: Is the Equipment Sited Outdoors?

<input checked="" type="checkbox"/> Yes

(Note - This section applies to unenclosed outdoor equipment and to equipment with contractor-supplied enclosures)

8b: Max. Permissible PWL if Outdoors

8c: For Outdoor Equipment, Copy Line 8b

63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
127	120	113	110	108	107	107	106
127	120	113	110	108	107	107	106



Rev. 1, November, 1996

Date	12/1/96
Project	Appendix C-6: Diesel GenSet
By	DAN
Sheet	1 of 1

to be used in conjunction with NASA LeRC "Guide for Specifying Equipment Noise Emission Levels"

Diesel Generator Set, On-Skid Enclosure, Outdoors

SCHEDULE A: INSTALLED ENVIRONMENT

A1: Approximate Volume of Host Space or Sound-Isolating Enclosure

300

Click in the appropriate box (for use in Contractor Submittal Sheet)

Volume Designation	Very Small	Small	Medium	Large	Free Field
--------------------	------------	-------	--------	-------	------------

Cubic Meters	55 - 140	140 - 700	700 -7,000	> 7,000	Outdoors
--------------	----------	-----------	------------	---------	----------

Click appropriate box

A2: Tabulate Sound-Absorptive and Sound-Reflective Areas in Square Meters

(Note - If Outdoors with no reflecting surfaces, use Absorbing Area = 200 sq. m.)

[illegible]

Sound-Absorbing Materials	1
Glass Fiber	50 mm or thicker
Mineral Fiber	50 mm or thicker
Basalt Wool	50 mm or thicker
Open-Cell Foams	75 mm or thicker
Tectum on 40 mm airspace	50 mm or thicker
Acoustical Ceiling Tile	on 400 mm airspace
Hanging Acoustical Baffles	50 mm or thicker
Sky, Open Doors & Windows	

Sound-Reflective Materials
Brick, Stone, Concrete
Wood, Glass, Metal
Tile, Plaster
Gypsum Board
Closed-Cell Foams
Ground

A3: Total Absorptive Area (Col. 1)

200

6g. High Equipment Density: more than 5 pieces of equipment

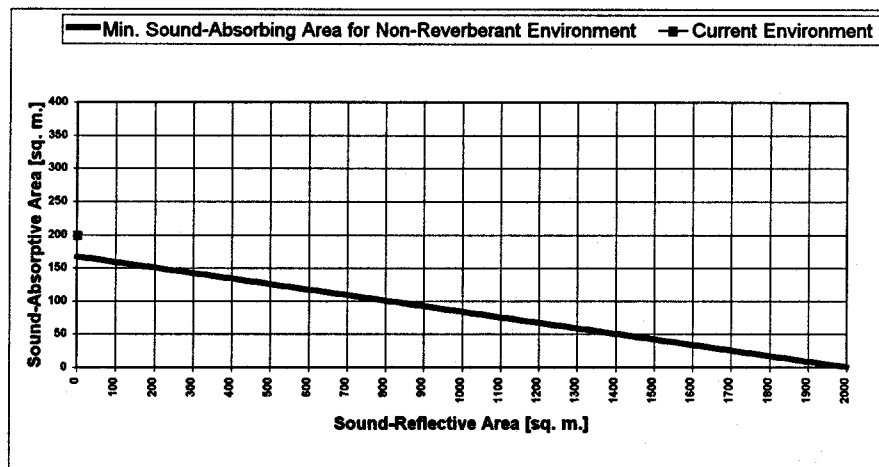
0

LOCATE THE POINT ON THE GRAPH CORRESPONDING TO THIS COMBINATION.

IF THE POINT IS BELOW THE LINE, THE ENVIRONMENT IS REVERBERANT.

IF THE POINT IS ABOVE THE LINE, THE ENVIRONMENT IS NON-REVERBERANT.

A5: If Reverberant, Enter "Yes" here and -5 in Col. 1 of Worksht. Line 6f

No

APPENDIX D: OPTIONAL EQUIPMENT SOUND-LEVEL VERIFICATION TEST FOR USE BY THE PURCHASER

The sound level measurement described below is an elementary method for post-installation sound level verification. It is not intended to supplant more comprehensive test standards. For critical applications, consideration should be given to using a more comprehensive standard such as ANSI/ASME PTC-36, "Measurement of industrial sound".

D.1 Instrumentation

Instrumentation shall consist of a Type-I or Type-II integrating sound-level meter including microphone, as specified in ANSI S1.4. If octave band readings are desired, a Type I meter is required along with a Type E, Class II octave band analyzer, as specified in ANSI S1.11.

NOTE - A Type II sound-level meter has acceptable accuracy ($\pm 2-3$ dB). If available, a Type I sound level meter (± 1 dB) is preferred. At no time should a Type III meter be used because its accuracy is not sufficient for acceptance testing.

Instruments shall be calibrated before and after the test by means of an acoustical coupler type calibrator (ANSI S1.4) and as recommended by the instrument manufacturer.

D.2 Loading

The equipment shall be operated at the loading conditions which were specified to the Contractor.

Where multiple, identical units have been purchased, only one shall be tested.

D.3 Measurement Locations

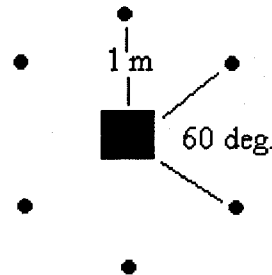
The area surrounding the equipment should be explored to locate the point of maximum sound level. Starting from this point, measurements shall be made in accordance with locations described in Table D.1 (Page 46) and Figure 2 (Page 47 and Page 48).

Table D.1: Field Verification Test Measurement Configurations

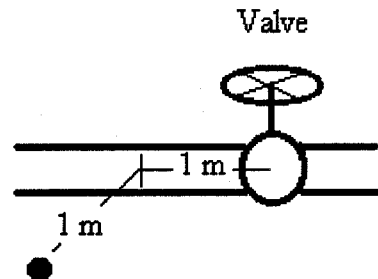
Equipment Group		Measurement Configuration
Group 1	<u>Heavy Machinery</u>	
	Reciprocating Engines	1
	Gas and Steam Turbines	1
	Rotating Electric Machinery	1
	Hydraulic Motors	1
	Hydraulic Pumps	1
	Valves, Throttles and Orifices	2
	Gears	1
	Compressors, Exhausters	1
	Blowers and Fans	1
	Chillers	1
	Boilers	1
	Heaters	1
	Dryers, Coolers	1
	Cooling Towers	5
	Machine Tools	1
	Electric Power Tools	1
	Pneumatic Equipment	1
	Industrial Trucks	1
	Fabrication Equip. greater than 10 HP	1
Group 2:	<u>Vents to Atmosphere</u>	
	Blowdowns, Relief Vents for Air, Steam, Nitrogen	4
Group 3:	<u>Piping and Ductwork</u>	
	Piping	3
	Ductwork	3
Group 4:	<u>Light Machinery</u>	
	Building Ventilation Fans and Blowers	4
	Fabrication Equip. less than 10 HP	1
	Pedestal and Shop Fans	4
Group 5:	<u>Transformers</u>	
	Oil-filled	1
	Dry-Type below 15 kV	1
	Liquid-Immersed	1

D.3.1 Description of Measurement Locations by Configuration

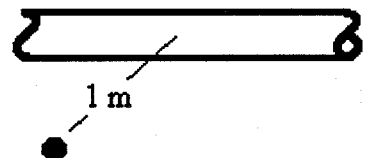
Configuration 1: 1 meter from equipment, at half the equipment height or 1.5 meters above ground level (AGL), whichever is greater, at six points at 60 degree increments in plan.



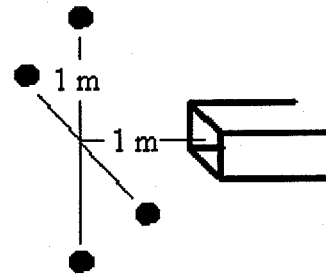
Configuration 2: At one location 1 meter downstream from valve or orifice, one meter perpendicular distance from piping, at elevation of pipe or 1.5 meters AGL, whichever is greater.



Configuration 3: At one location, 1 meter perpendicular distance from piping or ductwork, at elevation of pipe or 1.5 meters AGL, whichever is greater.



Configuration 4: One meter downstream from opening, 1 meter perpendicular to flow, four points at 90 degree increments circumferential around axis of flow



Configuration 5: One meter from each face of cooling tower serving as air inlet, at two positions 1/3 of cell width from each edge of cell, 1.5 meters AGL.

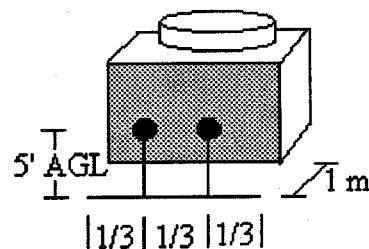


Figure 2: Description of Measurement Location by Configuration

D.4 Microphone

The test microphone should be placed so that it is protected from air currents (by means of a wind screen), vibrations, electric or magnetic fields, and other influences that might affect the readings. Location and orientation of the microphone shall be identical for measuring total and background sound levels.

NOTE - Microphone sensitivity is dependent on the direction of sound incidence. There is usually one preferred direction which produces the best approximation to flat frequency response. This direction varies among microphones and manufacturers, however. For example, the microphone of a Quest Model 1400 sound level meter should be pointed directly at the source of sound being measured. For other models, the user should request assistance from NEMP. Microphone location and position should be repeatable to within 12 mm and 10 degrees for all segments of the test.

D.5 Duration

For equipment that operates continuously, measurement duration at each location shall be no less than 1 minute unless the duration of operation (e.g., a pressure relief vent) is less. For cyclic or intermittent operation, no less than three cycles of operation shall be measured at each location.

D.6 Data to be Recorded

The sound level (A-weighted sound pressure level) shall be measured.

Data to be recorded shall include the equivalent sound levels, L_{eq} , and the maximum sound pressure levels (using a "Fast" time constant) observed during the period. In general, the L_{eq} is used to establish conformance with the specification. However, if the maximum sound level reading is more than 10 dBA higher than the L_{eq} , the maximum reading should be used for this purpose.

D.7 Correction for Background Noise

Background sound levels within the test location should be at least 10 dB below the total level (background plus machinery); otherwise, corrections must be made. If either background or machine sound-levels fluctuate appreciably, maximum levels should be recorded. If conditions do not permit a 10 dB difference between ambient and total, the following correction factors shall be used. Where this difference is less than 3 dB, the background sound level is excessive, and the location is unacceptable for testing.

Table D.2 Background Noise Corrections	
Difference Between Total and Ambient Sound Levels (dB)	Correction to Be Subtracted from Total Sound Level (dB)
< 3	Not Acceptable for Test
3	-3
4-5	-2
6-9	-1
10	-0

D.8 Averaging over Measurement Locations

Where measurements at more than one location are required, the arithmetic average of the readings shall be recorded.

D.9 Adjustment to Free-Field Conditions

Sound pressure level tests are ideally performed in large and/or sound absorptive environments, where reverberant sound does not influence the test results. Most vendor's noise emission tests are performed in such an environment. The MPSL criteria established in this guide compensate for excessive reverberation where anticipated, and therefore refer to this ideal environment as well.

Most host environments possess some degree of reverberation and cause the measured sound pressure level to be elevated. The level increase due to reverberation is estimated according to the volume of the host space where the equipment is installed.

The following adjustments shall be subtracted from measured sound level data to approximate measurement results that would have been attained in an ideal environment.

Host Space Size	Volume	Adjustment
Very Small	2,000 - 5,000 ft ³	-7 dBA
Small	5,000 - 25,000 ft ³	-5 dBA
Medium	25,000 - 250,000 ft ³	-2 dBA
Large	> 250,000 ft ³	-1 dBA
Free Field	Outdoors	-0 dBA

Table D.3 Adjustments for Test Room Size

The measured sound level, adjusted for background noise and host space size, may then compared with the MPSL to verify performance.

E.2 Test Code Citations

ANSI S12.15	Portable electric power tools, stationary and fixed electric power tools, and gardening appliances --- measurement of sound emitted
ANSI S12.16	Guidelines for the Specification of Noise of New Machinery
ANSI B133.8	Gas turbine installation sound emissions
ANSI B93.71M	Test code for the determination of airborne noise levels of hydraulic fluid power pumps
ANSI B93.72M	Test code for the determination of airborne noise levels of hydraulic fluid power motors
ANSI/AGMA 6025-C90	Sound for enclosed helical, herringbone, and spiral bevel gear drives
ANSI/ASME B56.11.5	Measurement of sound emitted by low lift, high lift, and rough terrain powered industrial trucks
ANSI/ASME PTC-36	Measurement of industrial sound
ANSI/CAGI S5.1	Test code for the measurement of sound from pneumatic equipment
ANSI/IEEE C57.90	Test code for liquid-immersed distribution, power and regulating transformers
ANSI/IEEE C57.94	Recommended practice for installation, application, operation, and maintenance of dry-type general-purpose distribution and power transformers
ANSI/ISA S75.07	Laboratory measurement of aerodynamic noise generated by control valves
ARI 575	Method of measuring machinery sound within an equipment space
ARI RP 531M	Measurement of noise from fired process heaters
ARI RP 631M	Measurement of noise from air-cooled heat exchangers
CTI	Code for measurement of sound from water-cooling towers
IEEE-85	Test procedure for airborne sound measurements on rotating electric machinery
NMTBA	National Machine Tool Builders noise measurement techniques